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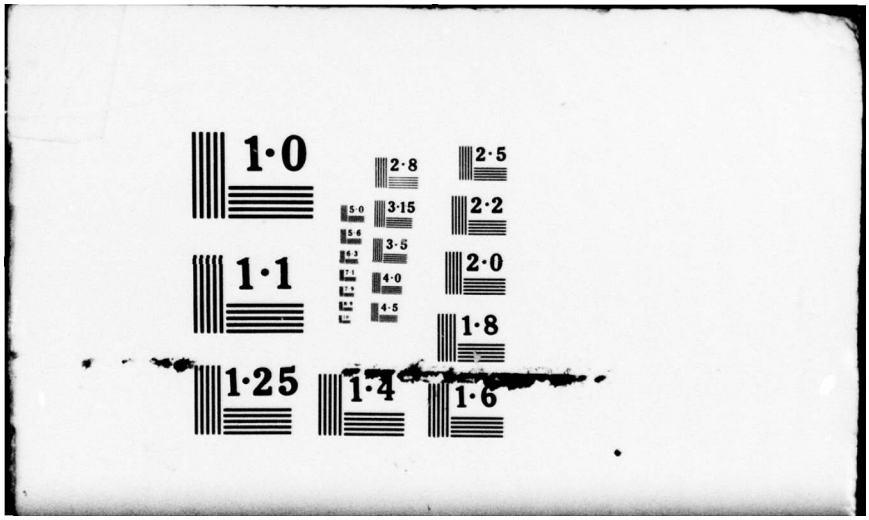
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This is a monthly publication presenting brief articles concerning recent developments in European Scientific Research. It is hoped that these articles (which do not constitute part of the scientific literature) may prove of value to American scientists by disclosing interesting information well in advance of the usual scientific publications.

The articles are written primarily by members of the staff of ONRL, with certain articles prepared by, or in cooperation with, members of the scientific

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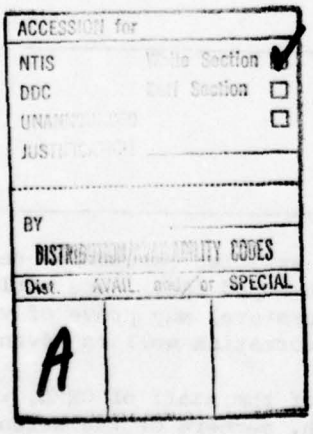

EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Aubrey W. Pryce and Victoria S. Hewitson

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BIOLOGICAL SCIENCES

A NEW ISRAELI METHOD OF MEASURING EYE MOVEMENTS

There are physiological, medical, and psychological reasons for the study of eye movements. Physiology is interested in eye movements for basic science reasons because the eye is an organ whose functions must be understood as those of any other organ. Medicine finds that eye movements are diagnostic of certain ailments. The eye is a highly directional receptor, and psychology is interested in its searching to receive information.

Because the eye is such a small and complicated motor system the measurement of eye movements is not an easy technology. When the interest is only in motor movements, it is necessary to measure only the position of the eye relative to the head, but when information on point of fixation in a visual scene is required, then position of the eye in space must be determined. Measuring the position of the eye in space is difficult because the eye is a moving system within a moving system (the head), therefore either the head position must be controlled or the relative eye position must be calculated.

Corneal reflection is a widely used method of measuring eye movements. It capitalizes on the front surface of the cornea being a spherical section that functions as a convex mirror reflecting any bright source impinging on it. The position of the corneal reflection, seen as a bright spot, is a function of eye position, and a photographic record allows measurement of eye position with an accuracy of 0.5-1.0 degrees. Control of the head position with a chin rest or a biteboard is common with the corneal reflection method, but the most ingenious technique for taking head position into account, and giving a photographic record of the point of fixation on the visual scene as well, was developed by Mackworth and Mackworth [*J. Opt. Soc. Am.* 48 (1958)]. Both the light source that is reflected from the cornea and a lightweight camera are mounted on the head of the mobile subject. The camera simultaneously records the corneal reflection and the visual scene. The corneal reflection is combined with the visual field through a beam splitter and appears on the composite photographic record as a bright spot over the part of the visual scene being fixated at the moment. The accuracy of the device is about ±2.0 degrees. Recent versions of the Mackworth system have taken the camera off the head by using optical fibers to convey the visual data to a camera located elsewhere.

Electro-oculography is another commonly used technique, and it is based on measurement of an electrical potential between the cornea and the retina. The potential varies with eye position, and it is measured by surface electrodes placed on the skin around the eyes. Electrodes placed on the outer canthi will record horizontal eye movement, and electrodes placed beneath the eye and on the forehead will record vertical movement. The accuracy of the electro-oculographic method is about 1.5-2.0 degrees.

In 1963 D.A. Robinson reported a new and very accurate approach that is electrical but not based on the natural bioelectric potential of the eye used in the electro-oculographic method [*IEEE Trans. Biomed. Electr.*, BME-10 (1963)]. Two coils of fine wire are wrapped on a contact lens and, with the use of two magnetic fields, both horizontal and vertical eye movements can be recorded with an accuracy of less than a minute of arc.

A disadvantage of the Robinson technique is the troublesome wires leading from the coils on the moving eye, and J. Ish-Shalom and Y.Y. Zeevi (Faculty of Electrical Engineering, The Technion, Haifa) have newly developed a magnetic technique that appears to solve the problem. A ferromagnetic ring is mounted on the eye with a flexible suction ring, and two small C-shaped coils are mounted on the side of the eye (the wires lead from the coils, with nothing attached to the moving eye). The ring and the two coils form two magnetic circuits in which the inductance of each coil varies as a function of ring position. Data from their bench tests show an accuracy of about one minute of arc and a linearity of 5% over 20 degrees. The new method allows measurement of eye movement in two dimensions. (Jack A. Adams)

OPTOELECTRONIC DEVICES IN DIAGNOSTIC OPHTHALMOLOGY

While the use of high-power pulsed lasers is well known for retinal surgery, low-power CW lasers have been proposed for diagnostic purposes only recently. They are being tried out clinically at Moorfields Eye Hospital in London along with other optoelectric devices, such as low-light-level television (LLLTV) cameras, digitally generated TV displays, and LED arrays. Minicomputers are used for processing, recording, and analyzing the visual evoked potentials due to such TV patterns or to others generated by the use of low-power lasers.

These were discussed in a talk given on 30 January at University College, London, by Dr. Uday B. Sheorey, who received his PhD there in electrical engineering in 1970, then joining International Computers Ltd., Stevenage, Herts., to undertake research on magneto-optic laser-beam storage. In 1972 he moved to Prof. G.B. Arden's group in the Department of Visual Science, Institute of Ophthalmology (Univ. of London).

This group has found that checkerboard and grating patterns produced on TV monitors are far more versatile than most earlier methods for presenting controlled stimuli to one or both eyes (independently but simultaneously) or to sectors of the visual field in order to assess the objective and subjective performance of the eyes and the visual system. The repetitively presented test patterns are generally of low contrast and can be mixed with other video signals, apparently without detriment to the test. Thus, children's attention and visual fixation can be maintained by including videotaped cartoons or live images of their accompanying parents, while adults naturally fixate on the center of the screen.

For spatiotemporal analysis of the evoked potentials, an array of 25 or 36 electrodes is attached over the visual cortex, and their outputs are cross correlated with the stimulus. For studying amblyopia, in which one eye's messages are more or less disregarded by the brain, two TV displays are used, and indications of suppression of the resulting sensation in one eye or the summation of the two are sought in the cortical responses. Their correlations with the stimuli show the modulation-transfer characteristics of the eyes without the difficulties of the patient's having to verbalize his sensations. In this way it is possible to determine whether an eye can see even though its output does not reach the higher centers.

The rate of production of visual pigment in the retina determines both the sensitivity and the dark adaptation. To measure it, the retina, after a quarter of an hour in the dark, is presented with a pattern of stripes, and the recovery from the resulting bleaching of the pigment is observed. In order to avoid the need for extremely high-speed photographic films and the delays in processing them, Sheorey and his colleagues utilize a solid-state LLLTV camera, which is able to see in dim moonlight and thus does not require illumination that would hide the phenomenon being observed. A Plessey integrated-circuit digital memory capable of holding 4 TV frames with 256 × 256 resolved spots, each quantized to 8 bits, is able to store the information from successive scans, permitting their automatic comparison in the analysis of the observations.

Fluorescein angiography has ordinarily been used to observe the flow of blood through the arteries and veins of the retina, but it is a slow and sometimes unpleasant procedure. Instead, Sheorey has introduced Doppler techniques for measuring the rate of flow by means of one or two 1-mW polarized He-Ne laser beams directed at a retinal blood vessel. A photomultiplier and correlator are used to read out the flow rate as a tone in the ophthalmologist's ear, permitting him to concentrate on keeping the beams aimed at the point of interest. No restraint on the patient is needed apart from chin and forehead rests.

In the case of patients with opacities in the cornea, lens, or vitreous humor—cataracts or floaters that blur the image—a sharp (if perhaps distorted) retinal image can often be obtained by utilizing the coherence of laser beams, and two such beams can be made to interfere to produce a pattern of parallel lines over whose lengths the eye readily integrates. Their positions, contrast, and spacing can be varied to assess the functioning of the retina and that part of the visual system beyond it. This assessment is needed, for example, in order to decide whether surgical removal of the opacities is merited. A He-Ne laser is used for this purpose,

its deep red color having the additional advantage of minimizing scattering of the beams, which carry only a fraction of a milliwatt.

Although the ophthalmologists with whom Sheorey works were at first unready to think of the laser as useful for anything but the photocoagulation of retinal hemorrhages, neovascularization, or weak spots where detachment might begin, they are now accepting its use, at least on an experimental clinical basis, for a variety of diagnostic purposes. They are also beginning to make use of the other optoelectronic apparatus mentioned above as well as various advanced signal-processing techniques for integrating and correlating evoked voltages. It can be anticipated that such equipment will be used more and more by ophthalmologists in the next few years. At present, however, it seems likely that the UK is ahead of the US in this field because the National Health Service sends patients with complicated ophthalmic problems to Moorfields Eye Hospital from far and wide, making it possible to gain a great deal of experience with these new techniques. (Nelson M. Blachman)

STAGING THE PERILS OF NON-IONIZING WAVES

It was not really a stage, but a *stage*. I was slightly puzzled by the word on an announcement from Bordeaux entitled: *"Sécurité du personnel exposé à une ambiance electromagnétique"* (safety of personnel exposed to an electromagnetic environment): 15, 16, 17 November 1977. One was being invited to participate in a *stage* whose *orientation* was described in terms of a brief background statement, an objective, and a plan of study.

What it amounted to was a three-day course of instruction conducted by an initiator and a small group of experts. I do not know where to find the word's current meaning. The standard dictionaries are not very helpful. Thus, Cassell: *Stage*: Term of probation, study, residence, etc. (for law students, etc.). Petit Larousse: *Stage: Temps pendant laquelle l'admission dans un corps reste provisoire, et à l'issue duquel il est procédé à une admission définitive, à une titularisation."* Since the *stagiaires* spent their three days closeted in the country, sitting for eight hours a day in a conference room miserably devoid of "No Smoking" signs, taking meals and coffee breaks together rather in the manner of a jury, the use of the word in English slang to mean "the privilege-period of a convict's imprisonment" (Partridge) rings true. And although at the end there was no admission ceremony and no degrees were conferred, we were entitled to a certificate of attendance and we were released from bondage. We could, if we cared, call ourselves old stagers or "persons (or occasionally animals) of experience" - a term derived, says Partridge, from the Old French *estagier*. Dare I suggest in these august pages that the instructors might well have been called stage-coaches?

Organizing and running *stages* is the business of ADERA, in common with a number of other such associations that have sprung up in France in recent years. ADERA stands for *Association pour le Développement de l'Enseignement et des Recherches auprès des universités, des centres de recherches et des entreprises d'Aquitaine*. It is a non-profit organization for instruction and research on behalf of the universities, the research centers and the manufacturing undertakings of Aquitaine, that fluctuating former province in western France which extends southwards from its one-time capital, Bordeaux, to the occidental Pyrenees. The prescribed functions are performed by means of *stages* held usually at the ADERA rooms at Saint-Aubin-de-Médoc about 15 km northwest of Bordeaux. ADERA also sponsors courses at the University of Pau in the Département des Basses-Pyrénées. In 1978 they go even farther afield with a four-day *stage* at Tucson, Phoenix, and Los Angeles. Expenses are met from fees, which therefore tend to be rather high—1800 francs for the one I went to—and the number of applicants accepted for each event is a compromise between the merits of small classes and the need to make ends meet.

Scanning the program, one sees that nearly all the courses offered will appeal primarily to industrial engineers or technical supervisors; some to technicians or mechanics; one to doctors and medical research workers; one to

the general public. So the association's major role would seem to be the instruction of industrial employees in fields pertinent to their on-the-job responsibilities. Examples: hybrid microelectronics in thick films; fundamentals of statistical techniques; introduction to chromatography; innovative and creative industrial procedures; the law of 1901 governing non-profit organizations.

The "electromagnetic" *stage* was organized in order to set forth systematically the information needed for a full appreciation of the following background statement, which I translate freely: "The activities of certain categories of personnel are such that these persons are exposed to an electromagnetic environment which may be biologically hazardous. The problem has been recognized, and in certain countries rules or standards have been defined at the national level."

Here I shall be less concerned with the promised systematic treatment than with items of possible interest to US readers within the framework: (1) physics and biophysics of non-ionizing radiation; (2) the conflicting safety standards adopted in different countries; (3) the Priore generator of biologically potent non-ionizing fields. Discussion of item (3) will however be reserved for a separate report; see also ONRL Conference Report C-14-77.

(1) Biophysics: Two engineers, J. Chastagner and R. Matabiau [Direction des Constructions et Armes Navales (DCAN), Toulon], skimmed through the physical theory, basing their talks on manuscripts which were given out to the class. These covered, in generally acceptable and familiar terms, the generation, propagation, and utilization of non-ionizing waves; the dielectric properties of materials and the peculiarities of energy deposition when a heterogeneous body, such as an animal, is irradiated. Attention was also given to methods of measuring or calculating power density at various positions with respect to electromagnetic (em) generators, antennas, and surrounding objects (including the observers and their measuring apparatus), with a view to locating danger zones and taking appropriate protective measures. The latter include simple avoidance when possible. When not, one can use field detectors which issue a warning, or protective clothing made of metallized fabrics. Sometimes it is desirable to screen a working area with metallic sheets or with grids optimally spaced with respect to the wavelength of the incident energy.

A.V.J. Martin (Centre de Recherche et de Technologie Spatiales à Noordwijk, Netherlands) spoke about heat deposition during microwave irradiation of large stratified biological objects, stressing the importance of body orientation and the probable occurrence of "volume resonances". By way of an original contribution he then descended to the microscopic level and gave the results of his calculations of resonant em frequencies for homogeneous non-absorbing cells of various shapes bounded by dielectric membranes. The fundamentals of the various resonant modes in a cell 100 μm in diameter are in the range 100-300 GHz. If absorption of radiation at the fundamental resonant frequency produces some observable biological effect, the nonlinearity of the system may result in excitation of harmonics, and periodicity of response with respect to frequency can be anticipated. The model used is almost a caricature of a real biological system; it would be surprising if phenomena attributable to resonances of this kind were not smeared out by absorption, intracellular heterogeneities, polydispersity of cell shape and size, to name only the most obvious of the factors ignored.

Martin continued in speculative vein by noting the accident—as Servantie called it—that the mitotic figure is identical to the field-distribution pattern in a cylindrical cell. He then discussed, as fact, the alleged superconductivity of cholesterol and some enzymes at room temperature. He hazarded the guess that the sensitivity of superconductivity, and of certain electron tunneling phenomena in thin films, to very low magnetic fields in the vicinity of the "critical" temperature may provide an explanation for the sensitivity of some animals to terrestrial magnetism. However flimsily supported such ideas may be, it is a fact that increasing attention is being paid to biological effects that may be produced by the magnetic component of em oscillations, particularly in the near field of an antenna where the electric and magnetic fields occur in different spatial patterns.

(2) Safety Standards: The *stage* provided an admirable opportunity for incompatible approaches to the question of microwave safe exposure standards to be set forth. The US point of view was ably presented by S.W. Rosenthal (Polytechnic Institute of New York, Brooklyn, NY). P. Czersky (National Research Institute of Mother and Child, Warsaw, Poland) dealt mainly with the attitude favored in his own country, adopted with significant modification from that of the USSR. B. Servantie (Centre d'Etudes et de Recherches de Biophysique appliquée à la Marine, Toulon), as chairman and convener of the *stage*, contributed many interesting comments based on his important studies of the neurophysiological effects of microwaves.

The maximum microwave (10 MHz - 100 GHz) power density to which one may be safely exposed for long periods, if one accepts the advice of the American National Standards Institute (ANSI), is one thousand times greater than that legally deemed safe in Poland and ten thousand times that permitted in the USSR for a member of the population at large. The reason for the discrepancy is to be sought in the concepts of microwave biology accepted in the respective countries. The US standard is based on estimates of the maximum increased thermal load imposed upon a person that can be dissipated by normal physiological mechanisms without acute ill effects. Roughly it corresponds to the threshold of sensation of warmth or of perceptible rise of body temperature. The existence of subtle or chronic effects of more modest exposures is either ignored or (in some quarters) denied. In the Iron Curtain countries, on the other hand, extensive observation has led to the belief that clinically observable disfunctions (if not indeed an identifiable "microwave syndrome") are elicited by chronic exposure to power densities far below the thermal threshold. It was revealing to hear a representative of a more-or-less totalitarian society contrast the mere absence of sickness with genuine good health, seen as the capacity to live creatively in full enjoyment of mental and physical well-being.

The Polish workers have for some time been doing epidemiological studies of personnel exposed occupationally to microwaves. Two thousand cases were followed over the period 1961-1972. The Polish safety regulations were introduced in 1973. It was observed that after several years of exposure to power densities at or above 1 mW/cm^2 (remember that the US recommended maximum is 10 mW/cm^2!) a large proportion of people complained of abnormal sweating, headaches, irritability and loss of sleep. There seemed to be some degree of temporary adaptation: the white cell population, somewhat variable in the early stages, with pronounced neutropenia, became normal in two or three years. Other symptoms receded during the fourth year, only to reappear during the fifth year, often with sufficient severity to dictate transfer to another occupation. Some persons, followed up to the tenth year, became unfit for work. Examination by objective tests revealed various abnormalities. These included electrocardiographic changes and a specific sensitivity to metrazol, monitored by the effect of the drug on the electroencephalogram. There was also in some cases a neutrophilia (up to 15,000/mm^3) of unknown origin. These matters are presented fully and critically in the recent book by S. Barański and P. Czersky, *Biological Effects of Microwaves* (Dowden, Hutchison and Ross, Stroudsburg, PA, 1976), together with much of the voluminous background information provided by experiments on animals and cell cultures.

In the light of such observations, the regulations established by law in Poland presumably have a fourfold purpose: to protect the population at large against electromagnetic pollution, to screen candidates for jobs involving excessive exposure to microwaves, to ensure that correct procedures are followed in order to keep these occupational exposures within tolerable limits, and to chart their effects. Also, one must assume, the regulations provide a legal framework within which claims for compensation can be fairly adjudicated.

Within the public, there are groups at special risk, including fetuses, the young, and the sick, but virtually nothing is known about the way in which em exposure may affect their condition. It is, however, a question of rather special interest to Poland, where, for instance, tuberculosis is still common. For prospective workers near sources of microwaves, an initial medical screening is mandatory if partial or absolute contraindications are to be detected. For those employed, there

is a routine annual check and, at any time, a special examination if requested by the employee or by the medical technical officer. These checks are quite thorough, including general, hematological, ophthalmological and neurological examinations, with chest x-ray, ECG and EEG.

Rosenthal, for his part, presented the US point of view in objective terms, with little attempt to promote aggressively what may, after all, prove to be an untenable position. While the ANSI recommendations of 1974 (see ANSI C95-3-1973 and C95-1-1974) have not been superceded, five-yearly revision is mandatory, and a new draft of the basic background document, which was given out to the class, contained amplified discussion of the problems of measurement, particularly in the near-field of an antenna and in places contaminated by microwave leakage. Furthermore, a new subcommittee, on medical surveillance, has been set up under ANSI Committee C95 to study suggestions for medical examinations. At the government level there is every evidence from the Annual Report of the Office of Telecommunications Policy that intensive interagency research, albeit hampered by lack of money, is going into all aspects of the microwave problem, including the characterization of subtle effects and their long-range implications. Collaboration with the USSR is maintained by exchange visits and by a formal agreement between the US Department of Health, Education and Welfare and the Institute of Municipal and Commercial Hygiene, Kiev. Nevertheless, according to Rosenthal, there is no program explicitly designed to get the sort of information, on such matters as thresholds, biological end-points, and chronic effects, that is essential for rational design of safety standards.

The ANSI, in preparation I presume for the second 5-year revision, is embarking on a survey of world literature on microwave effects in which each item will be rated against a numerical scale of factors contributing to scientific validity. This exercise in scientific detergency is admirable though not, I fear, without danger that the baby may be tossed out with the bathwater. For the moment, we are left with the recommendation of 1972, and so there is still some justice in Servantie's comment as Rosenthal ended his talk: *"La disparité continue"*.

Astonishingly, after the three days of *stage*, a physicist saw fit to ask: "Who is really endangered by microwaves?" Well, everyone; we are all bathed inescapably in a new and unique kind of pollution that—as Czersky put it—has increased a billion-fold over the last 30 years. Some of us carry an additional microwave load: those living near harbors, where they are exposed to ship radar; those who own microwave ovens; and those working on the land beneath the beams from gigawatt radio and television antennae. Clear understanding of the nature and degree of the associated hazards is obviously of the utmost importance, if only for the sake of distinguishing between false claims for imaginary, feigned, or unrelated illness and the possibly valid attribution of serious injuries, such as incipient blindness, to a nearby microwave transmitter. The vast medico-legal implications are certain to need clarification in the light of available scientific knowledge, at present sadly incoherent. (J.B. Bateman)

EARTH SCIENCES

GET THE LEAD OUT—AN ENVIRONMENTAL RESEARCH PROGRAM AT ISPRA

In the February issue of *ESN* a survey was presented on the research programs underway at the Ispra Laboratory of the European Joint Research Centre with emphasis on energy related programs. In addition to energy research, about 10% of the studies at Ispra involve the earth's environment, and one of the very interesting programs currently underway in this area consists of tracing automotive lead in exhaust fumes through various transfer pathways in the atmosphere and determining its intake by the human body. The method chosen to carry out this study involves using lead of a known isotopic composition in gasoline and analyzing environmental samples in a particular control area by mass spec-

trometry. The prerequisites for the study have involved: Keeping the isotopic ratio of lead in the source constant in time; assuring that this ratio is sufficiently different from the background; and keeping the lead ratio sufficiently different from that of other samples.

In order to differentiate automotive lead from other lead sources, only alkyl lead from the Broken Hill Mine in Australia is being used in the gasoline supplied to cars in the experimental regions, all of which are in Italy. The isotopic abundance ratio (Pb_{206}/Pb_{207}) of this lead is 1.04 which is significantly different from the 1.18 normally present in the general atmospheric environment of Italy. Italy was selected for the experiment which must be carried out on a relatively large scale for the following reasons: Its refining capacity exceeds its consumption and therefore a large part of its gasoline is exported; a high percentage of the alkyl lead used as an additive is produced by one company; imported lead is subject to government regulation, permitting control of the isotopic composition of any imported lead; and there is a high automotive intensity.

Two areas of Italy were initially selected for conduct of the experiment, Turin, and Cagliari and its province in Sardinia. The former was selected since there has existed for some time in the area an efficient network for monitoring atmospheric pollution including lead, while the local meteorological situation is characterized by periods of inversion with little or no air movement. Cagliari, on the other hand, was selected as a comparison region, since it is completely isolated and has a high traffic intensity with few industrial complexes. The most important aspect of selecting these towns is that all the automotive gasoline supplied to car owners in the areas will be controlled as to isotopic lead content. Vehicles entering from other areas would only contribute exhaust fumes commensurate with the current background which is not expected to interfere with the experiment.

To evaluate the impact of automotive lead on atmospheric pollution, measurement of atmospheric lead concentration, particle size distribution, and chemical composition will be carried out. By total lead and isotopic lead measurements, the contribution of automobile lead exhaust to products which are considered the principal ones ingested orally by man will be estimated. Products of particular interest include vegetables, drinking water, wines, and diary products.

The final aim of the study will be to determine medically from blood samples of persons in the two regions the contribution to human lead absorption produced by a given level of automotive traffic, and whether lead uptake differs among men, women, and children of various occupations. In particular the experiment will attempt to verify: The average lead level in human blood attributed to car exhaust fumes for people living in rural and urban areas; variation with age of the amount of automotive exhaust lead in the human blood; the shape of the curve of the lead isotopic ratios variation in the blood following a short term exposure; and the form of the curve of lead isotopic ratio variation in blood from the start of a long term continuous exposure and the curve of decrease following cessation of exposure.

It is expected that because of the complexity of the research, other cities and villages will be incorporated into the study depending upon the initial success of the venture.

As pointed out in the February *ESN* article, the Joint Research Centre's mission is to concentrate on general research applicable to all participating European country members, and this experiment (known as ILE) appears to follow that philosphy quite well. (Robert W. Rostron)

ONRL REPORTS

See the back of this issue for the abstracts of current reports.

ENGINEERING

MORE ON COMMUNICATION SYSTEMS AND RANDOM-PROCESS THEORY

A previous article (*ESN* 31-10:400) dealt with the application of martingale theory and stochastic calculus to the analysis of communication systems—one of the more controversial topics covered last August by the two-week NATO Advanced Study Institute on Communication Systems and Random Process Theory in Darlington, in northeastern England. There was more general agreement about the importance of most of the other topics: algebraic and probabilistic channel coding, multi-user communications, source coding, adaptive signal processing, propagation of signals in random media, and noise modeling. The present article describes some of the interesting points brought out by the papers and discussions in these areas.

The purpose of channel coding is to make it possible to transmit messages reliably despite a limited number of errors in the received symbols (usually 0's and 1's) resulting from noise in the communication channel. It is able to do so by encoding each successive block of k message digits in the form of a codeword of length $n > k$. The extra $n-k$ digits, which may be generated by a matrix-algebraic operation on the k message digits, serve as checks on the correct transmission of the latter and are generated in such a way as to enable the pinpointing of any errors provided there are not too many. Since they are not needed in the absence of errors, they are described as redundant, but they serve to increase the Hamming distance between different codewords, i.e., the number of corresponding digits in two codewords that differ. A minimum distance $2e+1$ permits the correction of up to e errors.

After a beautiful tutorial survey of algebraic channel coding and its relationship to combinatoric designs (such as are used in the statistical design of experiments) by Prof. Giuseppe Longo (Univ. of Trieste) (*ESN* 31-6:229), Prof. David W. Erbach (Concordia Univ., Montreal, Québec) discussed further intriguing aspects of this relationship, especially in connection with finite projective planes and the associated complete sets of orthogonal latin squares.

[A latin square of order n is an $n \times n$ array containing the symbols a_1, a_2,..., a_n exactly once in each row and in each column. Two are orthogonal if, when superposed, each pair $a_i a_j$ appears exactly once. A finite projective plane has $n^2 + n + 1$ points (and as many lines) with $n + 1$ lines passing through each (and $n + 1$ points on each line). For all known finite projective planes, the order n is a power of a prime, and the planes are desarguian (i.e., two triangles that are in point perspective are also in line perspective). There is no projective plane of order $n = 6$, but whether there is one for $n = 10$ is a famous unsolved problem of combinatorial mathematics, which led Erbach to look into coding theory. Only 2 mutually orthogonal latin squares of order 10 are known, and only 5 of order 12, while there would have to be 9 and 11, respectively, if the corresponding geometries should exist. If there is a plane of order 10, it is not desarguian; i.e., the corresponding sides of 2 triangles may meet in 3 noncollinear points when the 3 lines through corresponding vertices of the triangles meet in a common point.]

Dr. P.G. Farrell (Univ. of Kent, Canterbury) pointed out the great reduction in error rate that can be obtained by means of "soft-decision decoding," i.e., taking into account the confidence with which each received binary digit can be categorized as a "1" or a "0". Farrell described the hardware implementation, which involves certain compromises to avoid undue complexity, as well as test results. In the discussion of this paper, Prof. James L. Massey (visiting MIT), to whom the Institute was heavily indebted for many knowledgeable comments, credited Dr. G. David Forney (Codex Corp., Newton, MA) with the first investigation of soft-decision decoding. In connection with another coding paper Massey mentioned he had heard that, even for very short block lengths, the use of two successive channel codes in the form of "concatenated coding" (in which the symbols of the outer code are the blocks upon which the usually binary inner code operates) does better than any other known code in combating errors.

Massey's own talk was a tutorial discussion of the advantages and limitations of combining the channel-coding operation with source coding, which respectively introduce useful redundancy for combating errors due to channel noise and remove unnecessary informational detail from the output of the information source before it is coded for transmission through a channel. Source coding can be described as redundancy removal or information compression, and its output is the input on which the channel coding is designed to operate. The resulting channel code is fed to the channel, whose output goes to the channel decoder and then to the source decoder.

Massey showed that linear joint source-channel coding, which uses matrix multiplication (modulo 2) to get the channel code directly from the source output, entails an inherent loss of optimality (in terms of error probability or, equivalently, required number of channel digits) when the goal is the reproduction of the source within some specified nonnegligible distortion although there is no loss if distortionless reproduction is the goal. Prof. David J. Sakrison (Univ. of Calif., Berkeley) characterized source coding as a covering problem (i.e., a matter of choosing a set of overlapping spheres that together cover every possible source output, their radii representing the allowable distortion of those outputs) and channel coding as a packing problem (i.e., choosing the greatest possible number of nonoverlapping spheres representing the potential effects of noise on different messages, which must not be confused with one another).

In the course of a panel discussion on the practicality of source coding, Massey mentioned that Huffman coding has been used very successfully by AT&T for the compression of billing records, and Prof. Donald L. Snyder (Washington Univ., St. Louis) discussed its use in transcribing the second differences of long electrocardiograms. With 13 words in the code book and a 14th as a prefix to indicate no coding, a compression of 30% was achieved, but new computer storage media of larger capacity now obviate the former need for data compression. Sakrison described the compression of linearly scanned images to 0.8 bit per picture element by decomposing the resulting waveform into a piecewise linear part plus a remainder and using Fourier-transform coding of that remainder. The piecewise linear component changes slope whenever the remainder reaches a threshold.

In the session on multiple communication, dealing with channels having more than one input and/or more than one output, Prof. Jack K. Wolf (Univ. of Mass., Amherst) noted that, although feedback from receiver to transmitter cannot increase the capacity of a simple communication channel, it can increase the region of attainable pairs of information rates (i.e., allow a higher communication rate from one source to the destination for a given rate from the other) when the channel has two inputs (e.g., each taking the value 0 or 1) and a single output (e.g., the arithmetic sum of the two inputs). Prof. Kenneth W. Cattermole (Univ. of Essex, Colchester) (see ONRL R-2-72 by I.G. Kinnie, F.F. Kuo, and R.O. Rowlands) noticed a resemblance of this channel to duobinary coding (which combines successive digits from a single source in this manner rather than digits from separate sources), and Wolf was credited with having investigated such coding while at the Rome Air Development Center before Adam Lender (GTE Lenkurt, San Carlos, CA) independently developed this bandwidth-compression technique. In his own talk on the partitioning of space, time, and frequency for multiplexed communications, Cattermole pointed out that a given cable has a higher capacity when multiplexing by frequency division (allocating different frequency bands to different sources) than by time division (having them take turns in using the entire available band), as the former is able to take advantage of the statistical properties of the sum of the various signals while the latter cannot. In commenting on this paper, Prof. D. Yavuz (Middle East Technical Univ., Ankara) reported that differentiating a speech waveform with respect to time before clipping it enhances its intelligibility.

In the session on random propagation media, talks by Prof. J.L. Lacoume and Mme. Dr. G. Jourdain (Centre d'Etude des Phénomènes Aléatoires et Géophysiques, Grenoble, France) stressed the wide-sense stationary uncorrelated-scatterer (WSSUS) channel as a convenient idealization for investigating the optimum utilization of dispersive and fading

channels, whether communicating electromagnetically through the ionosphere or acoustically through the ocean. This model postulates reflection of the incident wave by a random set of point scatterers whose positions and velocities are independent of one another. The spread in their positions produces the multipath spread in the times of arrival of the reflections, and its reciprocal is the coherence bandwidth of the channel. The spread in the velocities of the scatterers produces the spread in Doppler shifts of the reflections, and its reciprocal is the coherence time of the channel. When the product of these two spreads is less than 1, the channel is described as "underspread," and, as pointed out by Dr. John G. Proakis (Northeastern Univ., Boston, MA), the intersymbol interference of slowly changing character then afflicting high-speed serial transmission can be combated by adaptive processing of the signal as picked up by one or more receivers.

Dr. M. Darnell (SHAPE Technical Centre, The Hague) stated that interference from other transmitters rather than the vicissitudes of ionospheric propagation is the problem in high-frequency radio transmission, and he suggested that use be made of sporadic E-layer propagation whenever channel evaluation shows it to be present, if only briefly. This phenomenon, which is ignored in propagation predictions, can, he said, be very useful. His colleague P.T. Nielsen stated that the WSSUS channel is pretty well confirmed for tropospheric-scattering communication. Prof. Stanley R. Robinson (Air Force Institute of Technology, Wright Patterson Air Force Base, OH) discussed the utilization of the underspread optical channel through the atmosphere, and he recommended the study of the attenuation, scattering, and dispersion caused by atmospheric turbulence, including the effect of the receiver's angular field of view upon the statistics of the received power and pulse length.

In addition to the Institute's Director J.K. Skwirzynski (GEC-Marconi Research Labs., Great Baddow, Essex), who was mentioned in the previous article (*ESN* 31-10:400), credit for the excellent program of the NATO Advanced Study Institute is due to its three co-directors: Prof. Bernard Picinbono (Ecole Supérieure d'Electricité Gif-sur-Yvette, France), who talked on adaptive signal processing for detection and communication, and presented algorithms for recursive adaptation derived from the theory of stochastic approximation; Prof. William L. Root (Univ. of Michigan), whose paper discussed nonprobabilistic and partly probabilistic channel coding and time-varying channels; and Prof. K.W. Cattermole. The Institute had NSF and US Army European Research Office support as well as NATO sponsorship. As mentioned previously, A.W. Sijthoff will shortly publish a volume containing the full texts of the Institute's nearly 50 papers, a number of which will serve as excellent introductions to various aspects of communication systems. (Nelson M. Blachman)

SYSTEM RELIABILITY: CONTINUOUS, DISCRETE, TOO MUCH, TOO LITTLE?

RELECTRONIC '77, the Fourth Symposium on Reliability in Electronics was held in Budapest, 4-7 October 1977. The Symposium was attended by some 150 participants presenting 60 papers on all aspects of reliability theory and its applications in the electronics industry. Presentations were made in both Russian and English with about two-thirds of the participants representing East European countries.

The Symposium was organized into three continuing sessions on reliability theory, component reliability, and system reliability. Although free to hop from session to session, the participants were encouraged to attend a single session throughout the Symposium, thereby creating a workshop-like atmosphere in each session. For the most part I participated in the session on reliability theory, which included papers in the areas of fault diagnosis, spare-parts allocation, system-reliability theory, and the mathematics of reliability theory. In addition an unscheduled round-table discussion on reliability theory vs practice was organized as part of the session. The most significant area of controversy dealt with the underlying foundations for system-reliability theory. At present, most on-going work in the area, including all the papers presented at the Symposium, use a Boolean model for system reliability. That is, they assume that

the system fails if and only if certain combinations of components fail. Typical of this approach were the several papers presented on K-out-of-N systems wherein the system fails if any K of its N components fail. With various assumptions on the component-failure statistics, one can do a complete reliability analysis for the overall system. Representative of this approach were the papers by J. Biernat (Institute of Technical Cybernetics, Technical Univ., of Wroclaw, Poland) and K. Zukauskas (Institute of Mathematics & Cybernetics, Vilnius, Lithuanian SSR) that appeared in the conference proceedings.

An alternative approach to system-reliability theory that generated considerable discussion both in the Symposium sessions and at the round table, though it was not represented by any formal presentations, was concerned with the use of continuous-degradation models for system reliability. A system may fail because one of its components has failed, but it also may fail because several of its components have deteriorated, though they are still within tolerance. If a system-reliability theory is to include such phenomena, one must use continuous models for the component performance, replacing the simple binary tools of the Boolean theory with deep analytical techniques. The advantage of such an approach to system reliability is a far more accurate description of the real world of system reliability. This is, however, achieved at the price of a more complex analysis and more sophisticated statistical models for the individual components.

Other highlights of the session on reliability theory included the paper by L. Gefferth (Budapest Engineering University, Hungary) on the "Diagnosis of Linear Circuits with Two Faults" and the paper by V. Amoia and R. Somma (Selenia Sp.A., Rome, Italy) "On the Semisimplicity of Transition-Rate Matrices." The former paper neatly exploits the bilinear relationship between component parameters of a linear circuit and its transfer function to reduce the problem of diagnosing a circuit with two faults from two dimensions to one. The paper by Amoia and Somma gives the first rigorous proof that the transition-rate matrices arising in non-stationary availability problems are semisimple. This intuitively palatable and highly applicable result generalizes the well-known theorem for the transition-rate matrices arising in stationary availability problems.

The session on electronic components was divided into subsessions devoted to the reliability of thin film and capacitors, semiconductor devices, LSI circuits, and electromechanical devices. Finally, the session on system reliability was devoted to the reliability of complex systems from a management (rather than theoretical) point of view. The presentations tended to the philosophical, dealing with approaches to system reliability rather than the specifics of the reliability problem.

The highlight of the session was the talk by W.A.C. Lacey (Rank-Xerox Ltd., Welwyn Garden City, Herts., UK) on the "Motivation for Total System Reliability." This beautifully planned exposition on the philosophy of reliability management may be summarized in Lacey's own phrase, "The criterion is not *better* reliability: It is more *accurate* reliability." Drawing on examples from a career in the reliability field, Lacey lucidly expounded on the thesis that system reliability should be planned to fit precisely the environment in which the system operates, with (the financial evil of) too much reliability being avoided every bit as much as unreliability. (Prof. R. Saeks, Texas Tech. Univ., Lubbock, TX)

EDITORS' NOTE

For another aspect of System Reliability see J.A. Adams "The Assessment of Human Reliability in Man-Machine Systems" page 116 of this issue.

ULTRASONICS AND METALLURGICAL STRUCTURE

Ultrasonic techniques are being widely used and they continue to be widely explored for the solution of an increasing variety of material examination problems, both in the engineering and medical fields. This is especially so if we include the exploitation of acoustic emission phenomena in the engineering case. However, applications at the routine level generally involve only simple acoustic phenomena. Even here in the classic nondestructive testing ultrasonic echo-ranging case, it is rarely possible to quantify with certainty a detected defect or to guarantee that every significant one has been detected. Further progress it would seem can only come from substantially greater appreciation of the complexities of the interaction between acoustic radiation and material and by exploiting carefully selected facets of that understanding. We need to know more about the generation of the acoustic signal, transmission through the material and its interfaces, scattering and reflection from defects or other surfaces, and interpretation of received signals—and how to use such knowledge. That particular acoustic phenomena can be very usefully exploited is well exampled by the work of Dr. C.R. Hill and his team of the Institute of Cancer Research, Sutton, Surrey, on the characterization of tissue by analysis of the variability of its acoustic backscatter (see Spiess *ESN* 29-4:146 and D. Nicholas, "An ultrasonic diffraction scanner for *in vivo* tissue characterization," Ultrasonics International Proceedings June 1977, IPC Sci. & Tech. Press Ltd).

The use of ultrasonics to provide information on metallurgical structure at the practical engineering level was the subject of a round-table discussion at the UK's Metal Society on 18 January. The discussion was organized by Dr. R.E. Dolby (The Welding Institute, Abington, Cambs.) and Dr. B.L. Eyre [Atomic Energy Research Establishment (AERE), Harwell], who by selection of the principal discussants provided representative coverage of a range of metallic structures and examination problems. Emphasis was on the effect and assessment of the metallurgical structure rather than on detection or assessment of defects *per se*.

General principles were ably outlined by Dr. M. Silk (NDT Centre, AERE) who reviewed knowledge of the interaction of acoustic radiation with a material, commencing with the simple case of longitudinal and shear wave propagation in an infinite isotropic medium, assumed in most current applications. He proceeded to discuss the effect of boundaries, noting the transfer of energy from one mode to another, the generation of surface waves (Rayleigh for one free space and Brekhovsky for two materials) and that energy may be transmitted along the surface at greater speed than through the material providing a head wave continually radiating into the bulk of the material. Turning to the "simple" case of a finite spherical defect, he treated the reflection and scattering of energy from it and the transmission of sonic energy into its shadow, touching on diffraction and the creeping wave, passage into the defect material and combination paths. Proceeding to a crack defect, he noted the various resulting waves; reflected longitudinal and shear, diffracted longitudinal and shear, and diffracted conical and surface waves, and touched on questions of mode conversion from shear to longitudinal and vice versa, stressing the greater effectiveness of the second.

To these complications must be added those caused by the material's not being isotropic. A granular structure results in acoustic scattering leading to (i) attenuation of a transmitted beam in addition to purely molecular absorption, and (ii) noise (reverberation). Metal processing such as rolling and extrusion results in directional characteristics in the material structure which are reflected in its acoustic properties. The acoustic properties may also be affected by residual stress developed during welding and other processing, which may also affect the physical nature of contained defects and in turn their acoustic properties as reflectors and scatterers. Further complications of frequency dependence in the acoustic properties and of constructive and destructive interference in propagation paths also arise, raising questions of the value of broadband rather than single frequency examination techniques.

Under the general topic "Inclusions in Steel," Dr. J.C.M. Farrar (Robert Jenkins & Co. Rotherham, previously of the Welding Institute) discussed work that had been undertaken jointly by AERE and the Welding Institute toward a method of assessing inclusions in rolled plate which are of importance to laminar tearing of butt welds. At the time the joint program was initiated, the major use of ultrasonic techniques was in the detection of gross inclusions and defects. The program objective was to extend these techniques to assessment of collections of inclusions in plate that develop as a result of modification of larger inclusions of silicates or MnS during the rolling process and which appear in finished plate as "clusters" or "tapes". While these defects could be found, they could not be analyzed or assessed by picking out a simple echo spike. Echo integration and counting techniques were investigated and the observed data compared with tensile data. Integration was found to be the most realistic, and clear correlations were obtained between the integrated signals and tensile information for both major inclusion types. A number of test equipments were accordingly built and sent into the field for evaluation. Here they were used with a much larger range of steel types many of which were found to give abnormally low, integrated echo levels compared with tensile information.

Despite considerable study and examination, including investigation of heat treatment effects and of the ultrasonic reflection and scattering processes at the inclusions, the causes of these low signals have not been totally resolved. They raise questions of (1) changes in the ultrasonic reflectivity of matrix/inclusion interfaces during heat treatment transformations; (2) reduction in the ultrasonic reflectivity of matrix/inclusion interfaces by imposed compression or residual stress; and (3) anomalous scattering of ultrasonic energy for no apparent difference in the inclusion characteristics. While there is some evidence that use of higher frequencies would have given some improvement in signal from the inclusions, this would have been offset by increased absorption due to grain structure in the matrix material. Key questions center on the extent of the gap between the inclusion and the matrix which is difficult to assess, and how this is affected by the material treatment. Again clouds of very small inclusions may not be detectable but may substantially affect the bulk acoustic properties of the matrix material.

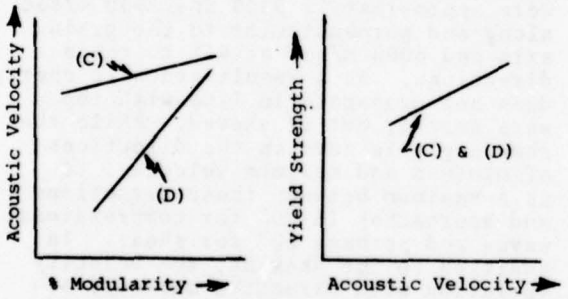
Dr. J.R. Tomlinson (CEGB, NW Region, NDT Centre Manchester) limited his discussion of stainless steel to welds. Normally it is not considered these can be satisfactorily inspected by ultrasonic techniques because of the difficult metallic structure. However, the highly anisotropic largely austenitic weld material that develops as the weld beads are deposited and the grains grow along the thermal gradient can have considerable order and a fairly uniform fiber-like structure. Exploitation of the acoustic properties of this structure can permit ultrasonic inspection provided the welding process and weld direction are carefully controlled and are optimized for subsequent inspection.

Apart from the granular structure producing scattering and attenuation, the fiber texture produces deviation and divergence of an acoustic beam due to the acoustic velocity in the material matrix varying with direction relative to the granular axis. Measured acoustic velocities reported for weld material were approximately 5300 and 5500 m/sec along and perpendicular to the grain axis and 6000 m/sec at 45° to these directions. As a result acoustic energy does not propagate in line with the wave normal, but is skewed. While the skew angle is zero in the directions of minimum and maximum velocity, it is a maximum between these directions and approaches 15-20° for compressional waves and perhaps 50° for shear. In addition to the skewing, the velocity variation with direction markedly affects the beamwidth of a transmitted ultrasonic beam, which is observed as attenuation. Attenuation is a maximum for paths along and perpendicular to the fiber axis and a minimum at about 45° to this axis. These effects require that careful consideration be given in setting up the welding process to provide a geometry that will allow inspection in a direction of minimum attenuation with due regard for the skewing. Apart from the acoustic effects attention must also be given

to any gravitational effects on the weld beads during deposition which affect their lay [See B.L. Barkie *et al* "Ultrasonic inspection of austenitic welds," J. Br. Nucl. Energy Soc. 15 (3), 257-261 (1976).]

Since every metal casting is an individual piece, it is important to provide foundaries with adequate on-line inspection techniques. In this connection Dr. P. Emmerson (British Cast Iron Research Association Alvechurch, Birmingham) described a technique based only on measurement of acoustic velocity for checking the quality of the metallic structure of iron castings used as brake blocks in the automobile and transport industry. The acoustic velocity in ferritic material is found to be dependent not only on the amount of graphite inclusion, but also on its form. Good ferritic material in which the graphite occurs as compacted nodules has a high acoustic velocity which is lowered as more of the graphite appears as interstitial chains and strips.

Although cast specimens with compacted graphite show much less dependence of ultrasonic velocity on modularity than those with degenerate graphite, the yield strength/velocity relationship is independent of graphite type (see figure). It would appear that both



(C) Compact graphite material
(D) Degenerate graphite material

the tensile strength and velocity in the two-phase cast material are primarily dependent on the effective area of the soft graphite constitutent rather than its volume. While other variables also have an effect on velocity such as carbides, the casting process can be controlled so that graphite is the important variable. It is possible therefore to perform a simple on-line go-no-go acoustic velocity test to assess material quality. This is carried out in a waterbath to eliminate difficulties caused by the rough casting surfaces.

Subsequent topics discussed were nickel-based and copper-based alloys both of which are beset with substantially greater acoustic attenuation than is the case for steel, and especially so in the case of nickel alloys of greater than 40% Ni. In copper-based alloys in which the attenuation is between that for steels and Ni alloys, attempts to use ultrasonic flaw detection techniques do not present too great a problem except that some faults don't give echoes. J. Bowden (Yorkshire Imperial Metals Ltd. Leeds), noting these difficulties, indicated some success in finding center-line defects or clouds of laminar defects in large diameter-to-length forgings by monitoring the back-wall signal level. Defects were found when this was not possible by normal monitoring techniques. On the other hand, attempts to use attenuation as a guide to grain size have proved unsuccessful.

The meeting was valuable in demonstrating that ultrasonic techniques can be effectively applied to provide practical metallurgical structural information beyond that generally recognized as defect detection. It also served to demonstrate how acoustic properties can arise that result in failure to observe defects during the course of normal routine ultrasonic testing. It is apparent, however, that extension of the use of ultrasonic techniques for routine practical examination will depend heavily on adequate appreciation of—and where possible exploitation of—the complexities introduced by the metallurgical structure in what is frequently considered a simple acoustic picture.

Discussion at the meeting appeared sympathetic to the potential value of increasing the interaction between groups working in such topics as fracture mechanics, acoustic emission, ultrasonics, and internal friction, and consideration is to be given by the Metal Society to the organization of a conference along these lines in 1979, possibly in conjunction with the Physical Acoustics Group of the Institute of Acoustics who have been considering similar possibilities. (A.W. Pryce)

GENERAL

THE TENURE PROCESS IN SPAIN: A LABOR FOR HERCULES

Most universities in the US should be close to completing the annual and often agonizing ritual known as the tenure-decision process. Invariably the candidate for tenure and/or promotion has no opportunity to be present at the numerous stages of the deliberations, and instead must be judged largely by prepared documentary evidence, consisting of curriculum vitae, preprints and reprints of publications, letters of recommendations, etc. This surrogate alter ego of the supplicant torturously wends its way through the numerous committees, designed to be the checks and balances of the system, and little information on progress is made available other than uncontrolled or controlled leaks. Such a system has often been attacked as unfair, degrading and dehumanizing, since no formal opportunity is given to the candidate to respond to claimed weaknesses or apparent inadequacies.

In contrast, the Spanish have a quite different system, which is very personal in its approach, in that a continuing assessment is made available and the candidate is present for almost every step of the process. Sounds good, or does it, for the procedure has been dubbed by many as the "inquisition incarnate". Let me describe how a typical tenure decision is made:

A fundamental difference from the US is that the Spanish university system is almost completely national in nature, and tenure is rarely given for a specific university. Thus, when an available position is posted, any qualified person at any of the 40-odd Spanish universities can equally apply. A post might be listed, for example, at the physics department of the Universidad Complutense in Madrid. Associate professors without tenure or lecturers with tenure, who believe they have the proper credentials in the desired specialty area, may apply. However, full or associate professors with tenure have "bumping" rights for the position. Since Madrid is the university heart of Spain, the position will undoubtedly go to one of these people. The available position then shifts to that person's school, which is invariably in a small town deep in the Pyrenees mountains. This is equivalent to a position at a major university like Berkeley or Carnegie-Mellon suddenly becoming one at East North West Prairie University. Oh well, travel, even to the boondocks, is broadening.

In a recent case, an initial group of 12 untenured faculty applied for a post in the north of Spain. They then waited for about two years, an average period, until the examination for the position was scheduled. At that time, the candidate's names were also publicly listed, allowing the competitors to scout one another. Since it does little for your future chances if you fail the exam, local flyweights usually drop out of contention at this stage. In the example cited, the final number of applicants was four.

A one month lead time is given for final preparation. At the start of this period, the candidates are presented with a list of 15 general subjects, such as (for physics) superconductivity, optical phenomena, quantum mechanics, etc. One of these topics will be selected by lottery at the time of the exam, and the candidates will then have three hours in which to write a detailed critical analysis of the current state-of-the-art in the field. While source material is permitted, only that in their possession prior to the lottery drawing may be used. The probability of having the proper books is small enough that detailed preparation is mandatory.

The exam, open at almost all stages to the public, is heard by a committee of seven senior professors, most with expertise closely aligned to that required for the post.

Day 1: Each candidate, in turn, discusses his qualifications, publications, teaching experience, etc; this is in effect an oral curriculum vitae. Questions of detail and amplification can then be asked by the committee and by the audience. Some embarrassing situations have developed where other candidates have attempted to discredit the speaker by questioning the validity of his stated qualifications (I use the masculine gender, because this

is the general truth in Spain; as in most countries, professors are usually men). Following these presentations, the committee votes by each member listing those candidates who he believes have passed; thus each candidate can receive from zero to seven votes. The ranking is then publicly announced but at this stage is only for informational purposes.

Day 2: A general subject is announced, e.g., the level of understanding of solid-state physics in Europe, and each candidate is given three hours to write a dissertation on the subject, without the use of notes. This will be graded by the committee that evening. In the afternoon of the same day the candidates present, in detail, their planned curricula and outlines for a number of undergraduate and graduate courses they intend to, or are expected to, teach. A new and much more critical vote is now taken by the committee on the basis of the first two days' performance. If a candidate does not receive four votes, i.e., if he is not listed on a majority of the ballots, he is eliminated from the competition. Those remaining can now stay for the duration of the exam. The relative rankings are however still announced after each section, and some have dropped out when they decided their cases were hopeless. In the example previously cited, three were allowed to continue, and all remained to the end.

Day 3: Each candidate presents a symposium on his research specialty. This is followed by a usually intensive question-and-answer period.

Day 4: The committee chooses, by lottery, a subject suitable for a graduate course lecture in the department in question. After two hours of open-book preparation, the candidate presents the lecture, considering the audience to be the class.

Days 5-7: This exam section seems outwardly similar to a PhD qualifying exam in the US, although I am assured by those who have gone through it, that it is a much more rigorous test of one's analytical understanding. The first of these days consists of a large but variable number of problem sets, taken under closed-book exam conditions and covering a broad range of topics centered about the specialty areas of the candidates. Following this, one or a number of phenomena requiring experimental verification are presented, with each candidate working individually. These problems can range, for example, from devising and carrying out an experiment to validate a physical constant, to developing and proving a technique to test a specific theory. The final part of this aspect of the exercise is to write up the devised procedure in a manner suitable for it to be used as a student laboratory experiment. This plan is then read publicly and given to the committee for grading.

Day 8: The lottery to choose the research topic from the list of 15, described previously, is performed. After completing the treatise, the formal part of the exam is over.

Day 9: All written parts of the exam having now been graded, the deliberations prior to final voting begin. These are done *in camera*, but in the presence of a representative of the Ministry of Education. Only one formal vote is taken; each committee member is allowed to vote for only a single candidate in the knock-out competition. The results are then announced to the candidates, who are usually surrounded by family and friends. The selections are randomly mixed to maintain the committee's confidentiality, and each member announces in turn one result; again any candidate can receive from zero to seven votes, with a clear majority vote of four needed for any one person to emerge as the winner. Incredibly, if no one receives four votes, a not that rare occurrence, the voting is not retaken but instead the entire selection and exam process is repeated from the very beginning. Oh, by the way, the winner only receives tenure at the associate's level. To become a full professor he must go through another knock-out competition, fortunately this time only covering the events of Day 1.

This is surely a more personal although arguably not a more humanistic approach than that used in most US universities. I leave it to the reader to decide which procedure he or she would prefer. (I.M. Bernstein)

MATERIAL SCIENCES

THREE FRENCH CENTERS FOR MATERIALS RESEARCH

A recent trip to Paris provided me with the opportunity to visit three major centers for materials research: The Centre d'Etude de Chemie Metallurgique of the Centre National de la Recherche Scientifique (CNRS), the Centre des Materiaux of the Ecole Nationale Supérieure des Mines, and the Laboratoire de Metallurgie Physique of the Université de Paris-Sud at Orsay. The diversity of the ongoing work coupled with different funding patterns, provided the opportunity to assess the quality and state of health of materials research in France today.

My charming hostess at the Centre d'Etude de Chemie Metallurgique-Vitry (Center for the Study of Metallurgical Chemistry) was Mme Simone Talbot, who organized a demanding but very interesting schedule in response to my somewhat off-hand remark that I wanted an overview of the laboratory's efforts. I visited seven or eight different groups and then gave a talk on hydrogen embrittlement. Some of the communicating was carried out in French, a hardly trivial undertaking for me.

The Center was established in 1939 by M. Chaudron, one of the best known of the French material scientists. He died recently, and at a ceremony held at the Journées Métallurgiques d'Automne (*ESN* 32-1:18) where the first Médaille Chaudron was awarded, the intensity of the eulogies given by Chaudron's previous students and collaborators was ample testimony to the respect in which he was held.

The research effort at Vitry, supported by a total staff of about 100 people, centers about the production and study of very high purity metals and ceramics. This is a continuation of Chaudron's policy of studying properties in only the highest purity of materials so as to eliminate, as much as possible, any secondary effects.

Various purification procedures constitute a large part of the program, since materials are made both for workers at Vitry and also on a service basis to other laboratories and universities in France. In particular, the Center is the primary source for high purity titanium. M. Lorthioir, who is studying the optimum ways to maximize purity, described how the titanium is produced by electrolysis of $TiCl_4$ in molten salts. Other processes, such as the Kroll and Hunter suffer because they cannot be operated continuously, require a large expenditure of energy, and because it is difficult with them to lower the amount of the major impurity iron, even using subsequent purification techniques. The key to the efficiency of the process Lorthioir is studying is to decrease the number of oxidation states present in the electrolysis bath. This requires careful temperature control and isolation of the anodic compartment, by a diaphragm, to facilitate chlorine gas removal. Proper use of the technique reduces the iron content (the major impurity) from 200 atom ppm (for repurified Kroll titanium sponge) to 0.2-0.4 atom ppm.

M. Bigot discussed the production of high-purity electrolytic grade chromium by a combination of three-pass zone-refining and subsequent annealing in hydrogen at temperatures up to 1500°C. The former process reduces the level of iron, nickel, copper, nitrogen, antimony, and sodium, while the latter reduces the level of the more critical impurities, (in terms of mechanical properties) carbon, oxygen and again nitrogen. In particular, the carbon is reduced to 15 ppm from an initial level of 140 ppm. The quality of the purification process was demonstrated by determining the temperature at which polycrystalline chromium undergoes a transition from ductile to brittle fracture. Purification reduces this temperature from about 90°C to 0°C.

Mme Talbot supervises the effort concerned with mechanical properties of high purity iron, particularly in the presence of dissolved hydrogen. The iron is produced by a two-stage technique which consists of first making $FeCl_3$ from FeOH, and then the iron by electrolysis. This is followed by annealing in hydrogen and finally zone refining. This procedure reduces the content of interstitials to 7 ppm carbon, 10 ppm nitrogen, and 13 ppm oxygen. The coarse-grained material obtained can then be used to produce single crystals of a variety of crystallographic

orientations. Such high purity material allows for a significant, but undetermined, amount of hydrogen to be introduced without the generation of internal damage, since the internal traps where damage can be nucleated are eliminated. Such material has quite remarkable properties in the presence of hydrogen. For example, the diffusivity at room temperature is about 7×10^{-5} cm^2 sec^{-1}, compared to values as low as 10^{-8} cm^2 sec^{-1} for lower purity iron. In single crystals, the presence of hydrogen promotes primary slip while suppressing the formation of secondary slip presumably by making cross slip more difficult, possibly by a decrease in stacking fault energy. This leads to the critical observation that hydrogen can enhance plasticity in iron. Such a finding has important ramifications for assessing the viabilty of currently proposed theories of hydrogen embrittlement. For example in susceptible structural steels, an enhanced plasticity could promote embrittlement resulting from strain localization and shear-controlled fracture. These studies and other aspects of hydrogen's effects in iron are being actively pursued, and the results are beginning to find their way into the English-language literature.

How to measure and assess the efficiency of the removal of impurities is a major area of research of M. Langron, who uses activation analysis techniques and, more importantly, Auger spectroscopy, i.e., the analysis of near-surface, low-energy, Auger electrons to identify and measure the amount of even light elements, with the exception of hydrogen. A significant effort is the development of a reliable quantitative analysis of the obtained Auger spectrum. Till now most investigators have relied on the use of standards with an accompanying large scatter. Langron has been studying the possibility of doing absolute measurements by using one of the elements in the matrix as a reference element, since the peak-to-peak amplitude of the Auger transitions for a given element is proportional to the corresponding Auger current. By knowing or calculating the atomic thickness of the layer being analyzed, the escape depth of the Auger electrons, the electron attenuation in the layer, and the contribution of the layer to the total signal (matrix effect), he claims that the number of atoms in a given layer can be directly calculated. He is currently using this approach in the study of passive films on stainless steels, surface segregation and depth profiling, and the effects of ternary elements in binary alloys.

An interesting study is being carried out by Mme Perez on the destruction of medieval stained glass by air pollutants, in particular the combination of SO_2 and H_2O. The ensuing chemical reaction leaches Ca, Mg, and, partially, S and P from the glass, promoting degradation. Part of the problem is believed due to the low SO_2 and high KO and CaO contents in medieval glass. Protection of the glass is expensive, and to date it has been difficult to obtain needed government support. The French are experimenting with polyurethane coatings for the windows of the Cathedral at Chartres; if this is successful in reducing the rate of damage, the effort may be expanded.

The research approach and mix is quite different at the Centre des Materiaux of the Ecole Nationale Supérieure des Mines de Paris. This major materials effort of the Ecole is located at Evry, about 20 km south of Paris, on the grounds of SNECMA, the only producer of French aircraft engines. The relationship between the two is, in the main, landlord and tenant, although some super-alloy studies are carried out for SNECMA on a contract basis. Although part of the prestigious Ecole, the atmosphere at Evry is very much that of a research establishment. Many people do teach at Paris, and students can obtain both Masters and Doctoral degrees by doing research at Evry, but the strong industrial flavor of many of the programs has somewhat muted the previously strong academic flavor. The change, as expected, is a result of economic pressures. Roughly 50% of the funding comes from the Research Ministry, 25% from the Ministry of Industry, and 25% from private contracts. While most would like a more academically-oriented mix, they recognize the inevitability of changing times.

I spent most of my time with M. Guttman and M. Pineau, both outstanding scientists who are well known in the US, particularly Pineau who studied at MIT. Guttman leads an effort concerned with understanding the effect of minor elements on the mechanical and physical properties of materials. This includes the use of electron-optic instrumentation,

such as the microprobe, the scanning electron microscope, and Auger spectroscopy; theoretical studies of the thermodynamics of adding ternary and quaternary additions to binary alloys; as well as traditional deformation and fracture studies. A prime interest is the understanding of how minor elements affect the susceptibility of structural steels to thermal (or temper) embrittlement, the premature intergranular fracture of steels used in such critical applications as pressure vessels. For example, they have recently completed a study on the intergranular segregation of sulfur, selenium, and tellurium in iron, using data obtained by either elastic backscattering or Auger electron spectroscopy. This segregation has been shown to be governed by the thermodynamics of reversible, thermally activated processes, which are not modified by the presence of carbon at such boundaries. Guttman, in cooperation with D. McLean who was at Evry for a year on leave from the National Physical Laboratory, Teddington, UK, is extending the study of grain boundary segregation to multicomponent systems, mainly from the theoretical point of view. They are concerned with synergistic effects where the mutual presence of surface-active solutes not only enhances their respective segregations but can even induce the segregation of nonsurface-active elements. The predicted results of these synergistic multicomponent effects is to increase the probability of potentially damaging grain boundary segregation, but also to introduce a critical temperature at which segregation is effectively eliminated. The results are being examined in stainless steels, super-alloys and complex steels.

Pineau is continuing his excellent work on the fatigue of super-alloys, powder products, and other structural alloys. He is primarily interested in the role of microstructure and such external variables as hold time at different stress (or stress intensity) levels, temperature, and the effects of the environment on fatigue crack growth rate and life. In a recent study on Inconel 718, the nickel-base super alloy extensively used for gas turbine discs, he investigated the low-cycle fatigue behavior of this alloy at room temperature and 550°C. He found that the fatigue life is substantially reduced at the higher temperature, with this effect more pronounced at lower frequencies of stress application. Fatigue also leads to softening of the alloy particularly at higher temperatures, reducing the stress carrying capacity of the alloy. The degradation in life has also been shown to be a strong function of the environment, and specifically of the presence of oxygen. This effect would have to be controlled before the operating temperature of turbines can be increased, a most desirable change since turbine efficiency would increase substantially.

Pineau is also involved in studies of the plastic crack behavior of pressure vessel steels, aiming at a more realistic picture of the process than can be arrived at by assuming that linear elastic fracture mechanics is controlling, and of the effects of thermomechanical treatments on the mechanical properties of high strength steels, particularly those containing manganese.

The most academic atmosphere was found, not unexpectedly, at the Orsay campus of the University of Paris. The metallurgy effort, part of the chemistry department, shares much in common with departments in the US, namely a lack of equipment, money, and students. Nevertheless high quality research continue as we academics like to believe (or delude ourselves), exigency creates the atmosphere for success.

Before outlining some of the research programs, the readers may be interested in how the program is structured. The laboratory is headed by Prof. P. Lacombe, who has under him two groups each headed by a maître de recherche. This position is roughly equivalent to an associate professorship except that it is purely a research position supported by CNRS with no formal teaching duties. This kind of funding, in fact, provides the connective link between government support and academic research. The two maîtres de recherche in turn supervise a group of seven who are either chargés de recherche (again supported by CNRS) or maîtres assistantes (equivalent to an assistant professor and supported directly by the University). Graduate students are either supported directly by CNRS through 3 to 4 year grants, by private companies, or occasionally by the University. They can be either third cycle (masters), PhD students, or Docteur d'Ingenieur students (this degree is only for those who have

graduated from an Ecole). Students receive a stipend varying from 2500 to 3500 Francs per month depending on their educational level. The student pays no fees to the University.

Within this hierarchal structure a variety of research efforts are going on. I will briefly list most, only spending time on one, the use of microradiography, since this reflects the time distribution of my visit. There are studies on how deformation mechanisms and recrystallization affect texture in titanium alloys and stainless steels, on oxidation and oxide properties in titanium and nickel-chromium alloys, on fatigue and creep of titanium alloys, on mechanisms of transformation and preprecipitation in titanium alloys, and on electron-optics oriented problems, utilizing secondary-ion mass spectrometry and electron probe microanalysis.

In addition there is a program on the effect of solute segregation largely supervised by M. Aucouturier, who is a maître de recherche. They are using C^{14} to study carbon segregation at grain boundaries and interfaces in iron-chromium and iron-nickel alloys, and of great interest to me, tritium to study hydrogen segregation in iron-chromium, iron-nickel-carbon alloys, and austenitic stainless steels. By using tritiated water, they are able to inject tritium into a material electrochemically, specifically into sites at which the tritium (and presumably the hydrogen) is trapped. The technique is quite simple in principle, and involves placing cathodically-charged samples in close contact with a photographic film so that the ionizing β emission from the tritium interacts with the silver halide grains of the emulsion. These grains are converted into silver filaments during development and provide a dark region image of the tritium distribution in the sample. The technique is deceptively simple, and the group has spent considerable time refining the procedure and improving resolution to where they can now distinguish submicron hydrogen distributions. It is my judgement that they have developed this application of microradiography to the point where they have the best facility in the world. The power of this technique is that it marks regions of high tritium (hydrogen) concentrations. Since these traps are invariable precursors to hydrogen-induced damage, their studies have been important in identifying much of hydrogen's role in environmental embrittlement, as well as how hydrogen interacts with the structure and microstructure of materials.

Many French researchers do not publish extensively in English-language journals. This is a loss to those ill-equipped or not inclined to read French, for, as described above, much of their work is of high quality and deserves to be disseminated to a much broader audience. There are welcome signs that they have grown tired of waiting for us to learn their language, and intend to publish more widely in English in the future. (I.M. Bernstein)

ORDER OUT OF DISORDER—GLASS RESEARCH IN EINDHOVEN

In this note I shall report on some of the research in glasses at the Philips Research Laboratory and at the Technological University, both of which are in Eindhoven, a bright modern city near the southern boundary of The Netherlands.

Philips has a commanding position in the European market for electronics and communications. Its products involve glass in many ways. There are new fields such as the use of very transparent glasses in fiber optic communications; there are also the older areas of glass use such as encapsulation and vacuum enclosures for cathode-ray tubes. For these reasons Philips has supported a program of R&D in glass for many years, and there are now about 10 people working in this area in Eindhoven, under the leadership of F. Meijer.

An obvious field for such a glass program is developing optical fibers for high data-rate optical communications systems. The work on glass fibers is split between two Philips laboratories. Fused silica fibers are being studied and developed for production at the Philips Laboratories in Aachen, Germany. They are following the usual practice of doing chemical vapor deposition of many successive layers with variable doping to produce a fiber core of very transparent glass surrounded by a cladding with a variable index of refraction

to trap the light in the core and to keep slightly off-axis rays from falling behind the on-axis rays as the light signals progress along the fiber. A novel feature introduced at Aachen is to use plasma heating to speed up the laborious process of making the many-layered glass structure from which small fibers are eventually pulled.

At Eindhoven the Philips glass group is attempting to develop a fiber that could be made in a continuous process and would be inherently simpler and less costly. The material is a many-component system based on a germanium-silicon-oxygen glass with additions of sodium. They pull the fiber core and its cladding from a double crucible, and the resulting fiber has a core diameter of 50 to 60 μm and an outer diameter of 100 to 150 μm. The attenuation of light in this fiber is presently 13 dB/km which is not low enough to compete with silica fibers that frequently fall in the range of 1 to 2 dB/km. However, values of attenuation as low as 4 dB/km have been reported for some many-component glass fibers so that there seems to be no fundamental barrier to reducing the attenuation somewhat further in this material. The Eindhoven group feels that such a glass will have many uses for communication links extending as much as a few kilometers. Once they feel that it has solved the primary purity and processing problems for this fiber, the effort will be turned over to one of the Philips operating divisions for development as a commercial product.

A novel program of glass studies was described by R.G. Gossink, who is developing a project to investigate glass surfaces. The need for such a program is apparent: most glass in electronic systems is joined to other materials or is used to contain a gas or liquid; the resulting interfaces and surfaces are often critical. A great many techniques for surface studies have been developed and applied to crystalline materials—especially metals and semiconductors. In insulating glasses, however, there are limitations. First of all, the lack of long-range order in the glass makes it unlikely that diffraction measurements yield much information. Second, most of the analysis techniques involve bombarding the surface with x-rays, ions, or electrons and analyzing some product that comes off the surface. In insulating materials this frequently leads to the production of a charged surface that alters the conditions of the experiment and may make the results meaningless. For instance, it is well known that in many ordinary oxide glasses the alkali ions migrate if an electric field is applied to the glass. So if a surface measurement system resulted in the development of charge on the surface of the glass specimen, the resulting electric field could change the distribution of alkali ions near that surface.

Gossink feels that XPS (x-ray photoelectron spectroscopy) is a moderately successful method of measurement for glasses. In this technique x-rays are incident on the sample and electrons emerge. A simple check for trouble in ordinary oxide glasses would be to ascertain that the alkali signal has not changed during the measurements.

Gossink and his co-workers have recently been working to establish conditions under which SIMS (secondary ion mass spectrometry) gives valid results for glass. In this technique ions are incident on the surface and the positive or negative ions emerging are analyzed. If an untreated glass surface is used, the charge buildup produces potentials of about 1000 V. However, a suitable analysis can be made by placing a tantalum plate with a 600-μm-diam. opening over the glass. The ion beam is swept in a raster over the opening. Under these conditions with 15-keV O^- ions incident on the sample, surface charging was only -15 to -45 V, and this can be taken into account in the analysis. It has also been found that voltages of this magnitude do not alter the alkali ion distribution. By changing the ion beam current the rate of surface erosion can be varied from 1 Å/hr to 1 Å/sec; the low rate is essentially a static surface-monolayer measurement, and the high rate can be used to determine concentration profiles below the original surface. This method has been used to measure the depletion of sodium in the surface of a glass exposed to hot water at 75°C for 30 minutes. Loss of sodium was seen to a depth of about 1000 Å.

SIMS is also being developed as a quantitative tool without the use of external standards by the use of an analytic expression for the emission of ions. Early experiments with this tech-

nique in commercial oxide glasses have given promising results. These studies by Gossink and his associates seem to confirm that SIMS can join XPS as a tool to study glass surfaces.

Another analysis technique that the Philips glass group is using with considerable success is Raman spectroscopy. Using the argon laser line at 5145 Å, Raman measurements of simple oxide glasses showed a rich spectrum of sharp lines. Most of these were sharper than the instrumental resolution of 10 cm^{-1} and were found in an energy range from 100 cm^{-1} to 1200 cm^{-1}.

By contrast, the infrared spectra of glasses are broad, lack sharp features, and are difficult to use for analysis. Such differences between infrared and Raman spectra are not seen in crystals, and it is strange that they should appear in glass. A hand-waving explanation that was given me was that infrared measurements excite lattice modes that are involved in changing dipole moments. These moments arise from special charged sites in the glass such as broken bonds and strongly polar ions. The dipolar fields fall off slowly so that the perturbations on the normal lattice vibrations are large and variable, leading to substantial absorption and broad bands. Raman spectroscopy involves the more nonpolar vibrations of the glass structure. These correspond to shorter-range quadrupole forces that are largely insensitive to the polar fields. As a result, the dynamical response of a structural group, such as an SiO_4 tetrahedron, would be nearly as sharp in a glass as in a solid. In any case the Raman spectrum is quite detailed; one such spectrum contained 11 identified features.

H. Verwey of the glass group and his associates have used Raman spectroscopy in an attempt to understand what "fining agents" do when added to a glass preparation. The reactions of the mixed chemicals when a glass is prepared give rise to gas, such as CO_2, which may be trapped in the liquid melt. Extensive stirring of glass melts helps in removing the bubbles, but it is difficult to eliminate all of the very small ones unless fining agents are incorporated. The addition of, say, 1% of As_2O_3 was studied. It was shown that an intermediate liquid phase was formed early in the melting process which contained arsenic as an As^{5+} ion. As the reaction continues to the end-product, some of the arsenic ions end up in groups where they are As^{3+}. In this process of valence change, molecular oxygen gas must be formed. It seems likely that it is this free oxygen that is responsible for the fining action of the As_2O_3.

A report on glass research in Eindhoven would be incomplete without reference to Professor J.M. Stevels, who was head of the glass program at Philips for many years. In 1973 he retired from Philips but continued his work at the Technological University in Eindhoven where he has been a staff member since 1961. His academic interests are fairly broad. He has had a continuing interest in cement; his recent studies are concerned with the effect of alkali on the hydration process which he thinks may become a strength problem if the sodium content of cement continues to increase. He is also interested in ceramics and the use of detergents in producing high-density white ware with superior strength.

Stevel's connection with glass and with Philips still continues. He has recently supervised a thesis by T.W. Brill, an employee of the Philips Research Laboratory, on the use of Raman spectroscopy to study crystalline and vitreous borates. Brill notes that some 10 borate groups are found in crystalline borates, and many of these are found in alkali borate glasses as well. A surprising result is that the Raman spectra remained unchanged, except for broadening, as the glass temperature was raised even above the melting temperature. The borate groups appear to be extraordinarily stable. Stevels will retire from his academic position within a year, but the work he has begun will continue through associates and students. His contribution to glass science over many years has been immense. It is typical of his active research spirit that in his last years he is heavily involved with Raman spectroscopy—the newest tool for glass research.
(Clifford C. Klick)

THAT VERY LAST LAYER OF ATOMS

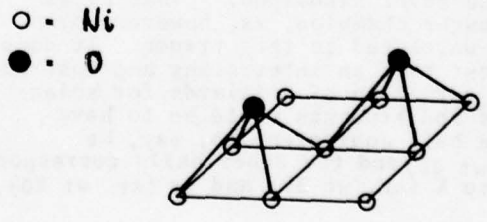
One conclusion from a visit to the Philips Research Laboratories in Eindhoven, the Netherlands, is that the research program there takes analysis of materials very seriously indeed. This function has broken out as a separate part of the Laboratory and carries the title "Structure and Analysis Group". The cost of equipment is so high and the expertise to apply it properly so specialized that a centralized group was found to be necessary. By contrast, Philips does not have a separate materials preparation group; this is done by the individual research groups.

The Structure and Analysis Group has broad expertise. Older arts such as chemical analysis, spectro-chemistry, and radio-chemistry are maintained, but much of the emphasis is now in the area of physical techniques. Among these are x-ray diffraction for structure determination and x-ray topography used for analysis of dislocations and for the study of Al in AlGaAs. Both transmission electron and scanning electron microscopes are used; they have ESCA (electron spectroscopy for chemical analysis), SAM (scanning Auger microprobe), and SIMS (secondary ion mass spectrometry). At the moment, apparatus is being assembled for EXAFS (extended x-ray absorption fine sructure).

As pointed out in earlier *ESN* articles (31-6:240-243), a bewildering array of surface analysis systems is available, each with its own acronym. At the risk of adding to the problem of learning this new language, I should like to describe another most interesting experimental technique that has been extensively developed in the Research Group of the Philips Laboratory by Dr. H.H. Brongersma. Called ISS, (ion scattering spectroscopy) or sometimes LEIS (low-energy ion scattering), it has been used to determine the character of the single outside layer of atoms in a solid. This is not so easy to do. Most other surface measurement techniques use x-rays or electrons which penetrate beyond the first layer of atoms so that some average of the properties of the surface layers is determined. In ISS the solid surface is cleaned, held in a high vacuum, and bombarded with helium or neon ions with energies of from 1000 to 3000 eV. The intensity of the incident beam may be as low as 3×10^{10} ions/cm^2 sec.

Most of the ions incident on the solid are neutralized. Those that penetrate beyond the first layer or are scattered twice are almost certainly neutralized. However, about 0.01% of the incident ions are scattered elastically by the surface atoms and come off still as ions. The number and the energy of these ions are then measured as functions of the incident and scattering angles. The energy loss suffered by the incident ion in the collision is a strong function of the mass of the scattering atom since conservation of momentum applies. As a result, well-separated peaks are often seen in the ion energy spectrum, and these can be identified with the presence and number of specific scattering atoms or ions. As a test case, Brongersma measured crystalline silicon alone and with the addition of bromine to the surface. The single dangling bond at each silicon atom on the surface binds a bromine atom, and the bromide atomic size matches closely the lattice spacing of crystalline Si. As a result, a single layer of bromine should cover the silicon. Measurements with ISS as bromine was added showed that the scattered energy peak changed from one due entirely to silicon to a large bromine peak with the silicon peak reduced to less than 1% of its original value.

The power of the method is illustrated by work done on the structure of oxygen adsorbed on a Ni (001) surface. This problem had been studied before using LEED (low-energy electron diffraction) and other techniques, but it remained ambiguous with different interpretations proposed by various investigators. One interpretation was that the oxygen is so reactive that it starts to grow a nickel oxide crystal on the surface. The other was that oxygen assumes a position of four-fold coordination as shown in the figure.



Studies by Brongersma of the ISS response for scattering of $^3He^+$ ions from Ni and O as the angle of incidence of the ion beam is varied (while keeping the total scattered angle constant) showed clearly that there was strong shadowing of the Ni by the O. This is in agreement, both qualitatively and quantitatively, with the model shown in the figure. From analysis of the shadowing, and knowing the sizes of the NI and O atoms and the $^3He^+$ ions, the height of the O atoms above the Ni plane is determined to be 0.9 ± 0.2Å.

Another problem being studied is the surface segregation of Cu-Ni and Cu-Pt alloys. In this case Ne^+ ions were used at energies of 3000 eV. When a 0.5-0.5 alloy of Cu-Ni is allowed to come to equilibrium at 400° C, only 3% of nickel is detected by ion scattering in the top layer. However, hydrogen absorption measurements consistently show a value of 20%. The difference is believed to be due to the effect of the adsorbed hydrogen. These results show, first of all, that the equilibrium structure of the surface layer may be very different from that of the bulk material,' and also that the structure may be strongly dependent on the kind of gas layer adsorbed on it.

The examples show the power of the ISS method in studying the nature of the final atomic layer in a solid. Not only can the atomic constituents of the layer be determined, but also the geometry of the atoms can sometimes be understood. The fundamentals of the method itself are simple since they involve elastic collisions between atoms and ions. This is not quite a "billiard ball" collison since masses of the colliding species are different in ISS. Brongersma once constructed billiard balls of different mass but identical size and made a motion picture of this more complex game with the Dutch billiard champion as demonstrator. The expert had great difficulty in adjusting to the novel situation. That he is no longer champion, is, however, probably unrelated to this trauma. It does suggest that an interesting and instructive variation of billiards for scientists and students would be to have a cue ball equivalent to, say, Ne (at. wt 20) and the other balls corresponding to K (at. wt 39) and Br (at. wt 80).

The Philips Research Laboratory, one of the great European laboratories in electronics and solid state research, is certainly very well equipped to analyze a wide range of materials and to determine their properties. It seems that this is an increasingly important requirement for a broad spectrum of optoelectronic research and development. (Clifford C. Klick)

VACUUM CONGRESS AND SURFACE SCIENCE CONFERENCE IN VIENNA

Vienna graced the combined Seventh International Vacuum Congress and Third International Conference on Solid Surfaces this past 12-16 September. As one might expect from the recent activity in surface science, the meeting was well attended and presented a bewildering array of information. To cope with the large participation, the Conference was organized somewhat like a five-ring circus. There were three oral presentation sessions, a poster session, and an equipment show, at most times occurring simultaneously. One might include a sixth ring, the attractions of Vienna, if one were so disposed. In spite of the complications of managing so large a meeting and coping with the multi-lingual participants, the hosts, the Austrian Society for Vacuum Technology, the Austrian Society for Atomic Energy, and the Technical University of Vienna, kept affairs running smoothly during the day and provided an interesting selection of evening activities to unwind the harried participants.

A variety of topics were addressed at the meeting. One may assess their relative importance by examining the session titles. Surface science dominated with seven technical sessions on surface analysis, five technical and two poster sessions on beam-surface interactions, and eight technical and two poster sessions on surface reactions. The properties of interfaces and thin films, subjects reflecting the electronics areas predominantly, were represented by four and seven technical sessions, respectively. Both also had one poster session. The study of vacuum science

occupied six technical and one poster session and the study of gaseous discharge effects one technical session. The first wall problems faced by fusion research were also well represented by three technical sessions. These were somewhat unique in that they directly addressed an identified technological problem whereas the other sessions addressed more general scientific areas.

It is impossible to review in detail a meeting as large and diverse as this one. Rather than attempt the impossible we have chosen to provide two summaries that reflect the perspectives of surface science and of electronics, which not coincidentally reflect the reporters' backgrounds.

On the surface science side of the meeting two major trends were evident. The first was the relatively quiet sessions involving surface analysis. Gone are the days of the recent past where battles, especially over Low Energy-Electron Diffraction (LEED) interpretations, shook the walls. The subject has matured considerably; most work reflected attempts to polish concepts of techniques which have been around for several years. Numerous groups are assembling or have assembled analytical systems with several of the spectroscopies combined in one vacuum system. This approach is necessary because any one spectroscopy gives an incomplete view of the surface properties. A. Benninghoven (Univ. of Muenster, FRG) gave a comprehensive summary of how the various techniques complement each other.

Two developments in low-energy electron diffraction are worth mentioning. The first is that of polarized electron sources which can be used in LEED experiments to give another parameter in evaluating surface atom geometries. Polarized LEED data should reduce ambiguities in intensity analysis efforts. Another aspect of intensity analysis progress is the demonstration of the voltage dependence of LEED intensities. From this data and kinematic calculations good agreement between theory and experiment has been obtained for the silicon (111) surface.

One new direction in analysis is the burgeoning use of angular dependent effects in Auger spectroscopy, photoemission spectroscopy, partial yield measurements, electron energy-loss spectroscopy, and desorption experiments. Much more theoretical and experimental research is needed; the inadequacy of theory was quite apparent in papers presented in Vienna and in the recent literature. An important concept here is that a surface effectively holds absorbed molecules at fixed orientation and that the angular resolved emission reflects that orientation. E. Ward Plummer (Univ. of Pennsylvania, USA) described two models whereby one may calculate the angular-dependent photoelectron yield given an absorbed surface molecule. Comparison with experiment then allows one to elucidate the absorbed molecule orientation. Several groups, for instance, T. Matsudaida, M. Niskyima and M. Ouchi (Kyoto Univ., Japan) and M. Scheffler, R. Kambe, F. Forstmann, and K. Jacobi (Fritz Haber Inst., Berlin, FRG) reported measurements on absorbed systems. Others, such as R.J. Baird, M. Mehta, and C.S. Fadley (Univ. of Hawaii, USA) and H.L. Davis (Oak Ridge National Laboratory, USA) used angular-dependent emission to study clean surface structure.

The important uses of ion beams in the medium and high energy range were also clarified. E. Taglauer (Max-Planck-Institut für Plasmaphysik, Munich, FRG) presented a very informative talk on this topic that detailed the use of ion scattering for chemical and structural measurements.

Ion scattering from surfaces at high (HE), medium (ME), and low (LE) energies has produced many spectra of a rich and varied nature. Here again, theoretical explanations are woefully lacking; the interaction cross section is the salient parameter. Medium and high energy scattering are coupled with ion channeling to separate surface from bulk effects.

And, of course, a meeting on surface science would not be complete without a couple of new acronyms (see A. Sosin, *ESN* 31-6:240 and 243) LEIS, MEIS and HEIS—referring to low, medium, and high energy ion scattering, respectively.

It is significant that there were so many sessions involving surface reactions. This is a reflection of the maturation of surface analysis referred to above. Researchers now trust the analytical tools enough to set them to work on reaction studies. There appear to be three general trends to the surface reaction work—chemisorption of CO, oxygen reactions with clean

metals, and catalytic reactions involving hydrocarbons. The first reflects a continuing saga—what is CO doing on a surface and when will there be enough analytical power for definitive measurements? Stay tuned to surface science for more episodes in this story. The latter two are relatively new directions for serious study involving the surface-sensitive analytical tools. A promising start has been made, but the interpretations are still sketchy.

For those participants interested in surface science as it relates to electronics and electronic materials, the oral presentations were somewhat of a disappointment. The best of these were generally review-type presentations, and while very interesting, did not present many new startling ideas or results. The poster sessions were much better, and the in-depth questioning possible under the poster presentation format usually revealed many important bits of information.

The interesting elements which have been extracted from the multitude of papers fall into two general categories: (1) advanced development of analysis techniques and improved quantitative and conceptual evaluation, and (2) new results on analysis of electronic material surfaces and interfaces.

The first category was discussed above. In the second, the role of foreign atom reactions on surfaces and the propagation of atoms parallel to or perpendicular to the surface provide the major scientific interest, of course. But theories of surface bonds and of chemisorption bonding potentials still are not adequate. Surface diffusion, absorption rates, and dissociative absorption experiments were reported with very little unambiguous explanation of what is really happening.

One area of importance to electronics interest involves the processes of atom movements in the interface between a substrate and a thin film. Some metal-silicon systems form silicides during thermal processing. Various surface analysis techniques have been applied to determine the relative motion of metal or silicon atoms into silicon from the system of aluminum oxide deposited on a silicon substrate. Simple diffusion concepts are inadequate to explain all of the phenomena reported at Vienna.

The above comments will serve to indicate what is happening in a few of the most energetic sub-areas of surface science, but also to give an opinion as to the important problems which remain.

Anyone interested in the proceedings should contact Dr. R. Dobrozemsky, Postfach 300, A-1082 Vienna, Austria. Lift some weights if you order the proceedings. They fill three sizable volumes and weigh about 10 kg. Try carrying that around in your suitcase sometime! [Larry Cooper (Office of Naval Research, Arlington, VA) and James S. Murday, (Naval Research Laboratory, Washington, DC)]

MATHEMATICAL SCIENCES

COMPUTER-AIDED NAVAL ARCHITECTURE AT DER TECHNISCHEN UNIVERSITAT BERLIN

The principal purpose of my visit to the Technical University of Berlin was to learn of the Institut für Schiffstechnik's (Institute for Ship Technology-IST) research activities in the area of computer-aided ship design (CASD) and ship hydrodynamic analysis. The CASD project at the Institute was begun three years ago by Professor Dr.-Ing. Horst Nowacki, Head of the Institute, when he returned to Germany after a ten-year period as Professor of Naval Architecture at the Univ. of Michigan, Ann Arbor. During my visit, Nowacki was appointed Director of the Fachbereich für Verkehrswesen (Division of Transportation Engineering) which, in addition to the IST, includes the Institute for Aerospace, Automotive, Highway and Railroad Engineering, as well as the Institute for Transportation Economics.

The initial CASD efforts at IST involved a great deal of basic graphics software development including both applications software (i.e., the mathematical software required for ship design calculations) and the systems software required to link one program to another and to interface the Tektronix graphics display console with the Institute's main IBM computer.

Tektronix, Inc. supplies a package of basic graphics software routines which are of very general purpose, but not tailored to the specific needs of a particular discipline such as naval architecture. Starting with this vendor-supplied suite of programs, Dr. K.-P. Beier (who heads the graphics group under Nowacki) has developed a computer graphics system called DINAS which is the acronym for Dialog Integrated Naval Architecture System. DINAS is written entirely in the FORTRAN language so that it is 100% portable (except for some of the input-output commands) and will be made available through government channels to German universities and industry. Some of the features of the DINAS system are its ability to handle large files such as a ship's lines plan (e.g., waterlines, section lines, etc.) by dynamically allocating storage in the main host computer, the ability to allow the user to control the execution of his job interactively, and a high-level, format-free command language which makes the system easy to learn and hence more attractive to the prospective user—whose background is in naval architecture and not computer technology. The portability, small size, and the well-conceived man-machine interface are seen by the CASD group at Berlin as major advantages of the DINAS system over other similar systems which have been developed outside Germany. With one main host computer and satellite mini-computers, each of which can support up to eight graphics consoles, it will be possible to achieve the goal of having many decentralized work stations all with access to the same large data base.

Concurrent with the development of the DINAS system, the Institute also began R&D efforts aimed at two principal problem areas—the interactive creation of "fair" ship lines and the computerized optimization of ship designs.

By way of background, the importance of a computerized ship-lines creation (design) system can best be appreciated in the light of conventional design office procedures. In general, the starting point for a new design may be either: (i) A parent design (i.e., the design drawings for an already existing ship), (ii) A collection of parent designs, or (iii) A set of geometric parameters that constrain but do not completely delineate the shape of the ship's hull. In the first instance, the goal of the designer is to develop a new hull form by a technique known as "lines distortion" which mathematically amounts to a perturbation, with or without rescaling, of the existing lines plan. In the second case, the designer's task is to design a hull form which is, in some sense, an optimum amalgamation of existing ships for which performance parameters such as ship resistance, propulsion, stability, etc., are known from empirical measurements. By and large, most ships are designed by one or the other of these perturbation or amalgamation techniques. Only when the new ship is radically different from existing vessels, as was the case with the supertankers, does the designer start essentially from scratch.

The IST group is developing the mathematical software required to deal with any of these three starting situations. Either of the first two design methods (i.e., a single parent ship or several parent designs) are handled by what is termed the "Standard Series Approach." Over the years, a host of Standard Series have been developed by individual naval architects, by national ship R&D organizations, and by ship certification organizations such as Lloyd's Registry of Ships in the UK, Det Norske Veritas in Norway, etc In a typical Series, the object is to interpolate a desired new hull form by systematic variation of certain characteristic ship parameters that refer to such properties as beam, draft, depth, prismatic coefficient, volumetric coefficient, and a variety of other geometric and performance variables. Standard Series differ from one another mainly in what parameters are considered to be independent variables (i.e., can be specified by the designer) and which parameters are the dependent variables. The choice of which Series a designer will use depends to a great degree upon the targeted new design.

The third design situation, in which the ship is specified only in terms of certain performance, capacity, and hull shape parameters, but is not to be derived from any existing parent ship, allows the designer a great deal more latitude. It also, however, places greater demands upon his knowledge of the basic principles of naval architecture. Any radically new design will also, of course, have to undergo more extensive experimentation and computer

model testing than a ship derived from a parent or parents whose performance and structural characteristics are known from experience.

An important problem in this type of *ab initio* design is that of mathematically defining or creating curve and surface shapes. (When dealing with parent designs, the lines plans can be given mathematical representation by digitizing the existing plans and using appropriate mathematical functions to fit the given data.) The IST group has further developed and implemented the techniques of *ab initio* design via "B-splines." With this method, the designer simply sketches a polygonal line having the essential shape properties of the desired curve and the mathematical software automatically computes a curve which closely mimics the polygon but which is "fair" (smooth) and twice differentiable, i.e., continuous in curvature variation. A full description of the mathematical methods used is given in the recently completed PhD thesis by Dr.-Ing Günter Creutz entitled "Kurven-und Flächenentwurf aus Formparametern mit Hilfe von B-Splines."

Under Nowacki's direction, the project on ship lines creation by computer is being carried out by Creutz, Dipl.-Ings. Wolfgang Jonas and Wilhelm Wolter in collaboration with Professor Fred C. Munchmeyer of the Univ. of Hawaii at Manoa.

Ship design optimization is the second of the aforementioned major software development programs being carried out at IST. The optimization software package provides the following capabilities: (i) Generalized problem-definition software, (ii) So-called "strategy"-software, and (iii) Software of auxiliary functions for supplementary parametric studies.

The problem-definition software establishes the problem formulation by means of user designation of those variables in the application program which he will want to treat as independent design variables. In defining the problem, the user must also specify, in terms of the relevant design parameters, the constraints and the objective function (measure of merit).

The strategy-software contains a group of optimization programs from which the user selects the particular algorithm which he wishes to use, e.g., linear or quadratic programming, sequential unconstrained minimization techniques, tangent search method, etc.

The role of the auxiliary functions software is to supplement the dialog for purposes of interactive optimal design. This subsystem is included in recognition of the fact that the designer may, before employing the automatic optimization techniques, wish to perform initial exploratory work such as parameter sensitivity analyses. Alternatively, following an automatic optimization run, he may wish to incorporate other considerations which are not readily quantifiable in order to modify the mathematically optimum design. Studies such as these, which may precede, accompany, or follow an optimization run, are conducted under the designer's own control. It is the auxiliary function capability that enables the designer to carry out these kinds of analyses totally under his own control. Since the designer will not, in general, be willing to accept without question the results of a computerized black-box optimization routine, the availability of this highly user-interactive mode of operation is essential to any system which is to be of practical use. (William J. Gordon)

APPLIED MATHEMATICS AT THE WEIZMANN INSTITUTE, ISRAEL

In 1945, Chaim Weizmann invited C.L. Pekeris from the Institute of Advanced Studies at Princeton to form a Department of Applied Mathematics at the newly established Weizmann Institute in Rehovoth, Israel. Pekeris then chaired the Department until 1973 when Lee A. Segel left Rennselaer Polytechnic Institute to assume the chairmanship.

At the time that Pekeris left Princeton, he had been working with Von Neumann on methods of solving problems using the then novel computers. I fortunately had been in contact with this work because a controversy between C.C. Lin and Pekeris had arisen over whether Plane Poiseuille Flow (pressure-driven flow between parallel planes) was linearly stable or not, and I was at that time

in the process of programming the solution of the stability of the shearing layer at IBM. I well remember the meeting at the IBM headquarters in New York with Von Neumann, Lin, Pekeris, and L.H. Thomas that preceded the calculations by Thomas who finally showed Lin to be correct in finding an instability. At the Weizmann Institute, Pekeris engaged in a program of developing computers which culminated in the development of the Golem B computer, a modern and powerful number cruncher. In addition to Pekeris, Joseph Gillis, who was a former student of Besicovitch, was a central figure in the formation of the Department by virtue of his broad research interests. Although now officially retired, Pekeris and Gillis continue their research activities.

A recent research interest of Pekeris has been in the area of relativistic hydrodynamics and, as an example, he has generalized the classical hydrodynamic solution for a spherical vortex first investigated by M.J.M. Hill (*Phil. Trans. Roy. Soc.*, London, Series A 185, 213-245) in 1894. A spherical vortex is like a smoke ring bounded on the outside by a spherical surface. The Pekeris relativistic generalization is in closed form for the case of an "incompressible" flow. Of course, the classical definition of an incompressible flow is one in which the velocity of sound is infinite. In the relativistic case, the sound velocity cannot exceed C (the velocity of light); Pekeris obtained his closed-form solution for the velocity of sound equal to C. Unfortunately the upper limit of the sound velocity that is physically realizable occurs in a gas whose particles move at the velocity of light (the ultrarelativistic case), and for this case, the velocity of sound is $C/\sqrt{3}$. Since for the case in which the pressure on the surface of the sphere vanishes, the pressure at the center is negative, Pekeris concludes that the relativistic effects in themselves do not make for "cohesiveness." However, he has only considered special relativistic effects and not the general relativistic gravitational interaction of the fluid with itself.

The program of software development in the Department is under the direction of Professor Zohar Manna, who is particularly interested in automatic verification and modification of programs. Associate Professor Aviezra S. Fraenkel is working on information retrieval and combinatorial games. Fraenkel is currently designing and directing the use of a full text retrieval system for the Responsa, a collection of rabbinical literature consisting of 101 volumes or 21×10^6 words of computer storage in Hebrew, Aramaic, and other languages. The system (a joint project with Bar-Ilan University) is designed to retrieve all and only relevant documents using a self-improving source. The system homes in using negative and positive feedback, clusters on partial answers, and comes up with new key words. There are also ongoing retrieval experiments using US patents as a data base. Fraenkel's work on combinatorial games involves studies of the strategy of computing solutions to typical game problems. However, many games fall into the class of NP hard (for which no strategy exists to compute a solution in a reasonable time); an example of such a game is a board game like chess or checkers. For an N × N board, the possibilities are of the scope of an N-powered polynomial. An example of a game that can be computed in a reasonable time consists of the order of e^N possibilities.

Associate Professor Bernard P. Zeigler works with experimentalists in using computers to help construct models of biological and ecological systems. The simulation involves the use of a high-level language to express the models which are then translated to a lower level language such as FORTRAN in a compiler. The model descriptions are stored and the storage is then organized into a coherent system.

Professor Isaac Moses Horowitz is studying how to make systems work despite uncertainties and attempting to develop a quantitative theory for this purpose. For the case of a simple (single loop) system, the bounds of the system output are being studied for uncertainties in the transfer function parameters as well as external disturbance excitations.

Some problems in the field of biomechanics such as peristaltic flow, cilia driven flows, and a molecular mechanism for muscle action are being studied by Nadav Liron while multilevel adaptive techniques for the numerical analysis of partial differential equations are being pursued by Achi

Brandt. The automatic shifting from coarse to fine meshes and back in connection with numerical fluid mechanics involving shock waves and boundary layers is an example of the problems being studied.

Professor Lee A. Segel is continuing his work on biological applications and has, most recently, made a theoretical study of receptor mechanisms in bacterial chemotaxis. When the number of chemical attractant molecules that are bound to a bacterium's receptor molecules are changed, there is a probability in favor of the bacterium suddenly changing its direction of locomotion. Segel has developed a one-dimensional model with "memory" for this phenomenon that agrees quite well with experiment. He has also become interested in theoretical physical chemistry and is working along new lines in electro-osmotic desalinization.

The Weizmann Institute is basically a research institution, however the graduate program in Applied Mathematics has operated through the Institute's Feinberg Graduate School since its inception in 1958. In 1967, a charter was provisionally granted by the Board of Regents of the University of the State of New York, and in 1972 the charter was granted absolutely. At present, some 30 MSc and 40 PhD candidates in Applied Mathematics are enrolled. The overwhelming majority of the faculty have received their graduate training outside Israel, and the Department enjoys the additional cross-fertilization of distinguished visitors.
(Martin Lessen)

ONRL REPORTS

See the back of this issue for the abstracts of current reports.

MECHANICS

THE AERODYNAMICS INSTITUTE AT THE EIDGENOSSISCHE TECHNISCHE HOCHSCHULE (ETH) REVISITED

Consider a glass tube which is closed on one end and open at the other. If heat is applied to the closed end and the tube is cooled over an area next to the heated region but further away from the closed end, the gas column within the tube will be destabilized and begin to oscillate provided certain conditions are satisfied. These conditions are that the ratio of the tube radius to the thickness of the boundary layer of the oscillating flow in the tube is of the order of 10, and that the temperature at the hot end of the tube is not so high that the resulting viscosity of the gas overdamps the oscillation. Prof. N. Rott of the Institute for Aerodynamics (IA) of the Swiss Federal Institute of Technology (ETH) in Zurich, who demonstrated a working model of a thermoacoustic oscillator to me in his office, has been interested in thermally-driven acoustic oscillations for some time and, in cooperation with his associate at the IA, Prof. H. Thomann, is studying advanced aspects of the problem along with the inverse problem of a temperature differential created by an oscillating gas column. These topics are among a number being studied at IA, some aspects of the program of which were covered earlier in October '76 in an article by Nunn and Barcilon "Engineering Research in Switzerland" (*ESN* 30-10:444). The chairs held at IA by Rott and Thomann were established by division of the chair previously held by Prof. Jacob Ackeret, whom I visited in 1956.

The thermal mechanism driving the oscillation in the gas-filled tube can be understood in terms of the following elementary model; the oscillation alternately moves hot gas across the boundary from the heated to the cooled region and cold gas in the opposite direction. Heat is removed from the hot gas causing it to contract, and is added to the cold gas causing it to expand. If the phasing of the gas contraction and expansion

is correct, the oscillation will be driven, thus the apparatus becomes a rudimentary Stirling engine with no mechanical moving parts. The action of the boundary layer in moving the gas can be pictured in terms of being peristaltic in nature. To adjust the frequency of oscillation such that the work output is maximized, the gas column is weighted by a column of water as shown in Fig. 1.

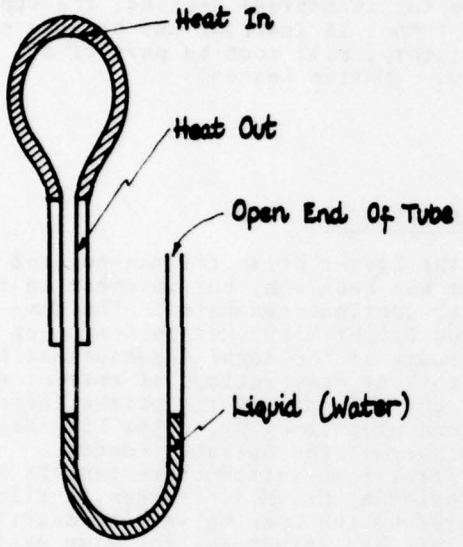


Fig.1. THERMOACOUSTIC OSCILLATOR

It can be appreciated that with the proper arrangement of check valves, work can be removed from the system in the form of water pumped against a pressure head. The thought that water could in this manner be pumped through an irrigation distribution system by solar radiation is intriguing.

The thermoacoustic effect was probably discovered first and accidentally by a Dr. Castberg of Vienna in 1804 when blowing a bulb on the end of a glass tube. Sondhauss experimented with a similar bulbed tube in 1850, and a description of the Sondhauss tube and a qualitative explanation of the phenomenon are given by Rayleigh in his "Theory of Sound." The effect was also noticed more recently by Kammerlingh Onnes in Leiden when, in 1908, he liquefied helium and exposed a tube to both room and liquid helium temperatures.

Rott and his group are presently investigating nonlinear effects in order to obtain limiting amplitudes of oscillation. These include finite-amplitude wave effects, flow separation in variable cross-section tubes, end effects, and the effects of variable viscosity and thermal conductivity caused by temperature stratification. It is hoped that these and allied studies may find practical application.

Studies on the effect of moving boundaries in inhibiting flow separation are under way. Flow separation occurs when a boundary layer experiences an adverse pressure gradient (the pressure rises in the direction of flow). To be sure, the adverse pressure gradient reduces the velocity of the flow outside of the boundary layer, but the important effect is to strongly decelerate and even reverse the flow within the boundary layer at which point the layer detaches itself from the boundary. It is the burden of a designer to avoid such situations and the resulting inefficiencies and shortcomings of fluid mechanical equipment.

Rott has found that by providing a boundary that moves at the flow velocity outside of the boundary layer, the boundary layer is thereby prevented from separating much in the same way that one energized by tangential (slot) injection remains attached. (Slot injection is a method of keeping flow attached over flaps on aircraft.) In this manner, Rott has kept the flow from separating in sudden expansions in ducts. He has also maintained attached flow about a pair of parallel cylinders that touch each other and roll on each other with the direction of rotation such that the outer surface of the cylinders move with the flow. The principal external flow direction is perpendicular to the plane determined by the axes of the cylinders. Lift can be obtained in this arrangement by tilting the plane of the axes while maintaining them perpendicular to the principal flow direction. In some respects, the resulting flow field resembles a jet-flap.

Rott then introduced me to another continuing interest of his, namely, nonlinear oscillation of mechanical systems. It is well known that an inverted physical pendulum can be stabilized in the vertical position by providing a vertical

displacement oscillation of the proper frequency and amplitude at its lower end. Conversely, it is also possible to destabilize an ordinary physical pendulum by vertically oscillating its upper end at the proper frequency and amplitude. The relevant algorithms are given by the Mathieu equation and have been known for a long time. Rott, however, is studying the dynamics of mechanical systems far beyond the point of such instabilities. One such system under study consists of a physical pendulum which swings about a pin on one end of a balancing beam-physical pendulum arrangement. (See Fig. 2.) The natural

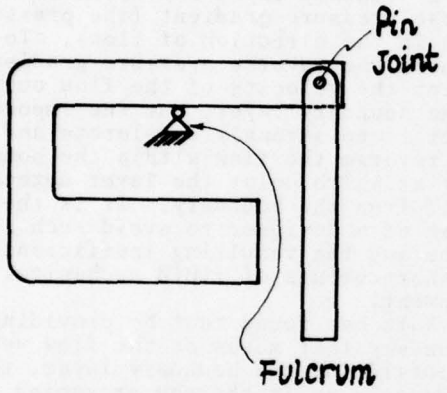


Fig. 2. DOUBLE PHYSICAL PENDULUM

frequency of the balancing beam-physical pendulum plus the pin-jointed physical pendulum attached to it at one end (two moving linkages total) is such that at the proper amplitude of oscillation, the attached pin-joint mounted physical pendulum will be destabilized; though it does not swing initially, it will begin to swing with increasing amplitude until the balancing beam no longer oscillates. After some time, however, the pendulum loses its energy to the beam and the energy of oscillation continues to move alternately between pendulum and beam. At larger amplitudes of oscillation including rotation of the beam and pendulum about their pin joints, the same alternating shift of kinetic energy between the two links takes place.

Another demonstration of nonlinear mechanical behavior for the case of a balancing beam with a physical pendulumn pin-mounted at each end showed even more complicated and fascinating behavior in terms of energy transfer between modes.

My visit to the IA closed with a tour of the laboratories which included the first closed-circuit supersonic wind tunnel (built in 1933, operational in the late 1930's) with a 40 × 40 cm test section, Mach no. = 2 and variable Reynolds number, and a subsonic wind tunnel 2 m × 3 m test section (100 m/sec). The subsonic tunnel is being used extensively for industrial testing; the supersonic tunnel is inactive and because of its history, will soon be part of a museum. (Martin Lessen)

WHAT'S FLYING?

The Kremer Prize for man-powered flight has been won, but interest in the subject continues unabated. The Man-Powered Flight Group met in London on 7 February at the Royal Aeronautical Society to hear descriptions of current efforts and a report on the prizewinning American program by Dr. Peter Lissaman, codesigner of the Gossamer Condor.

After some introductory remarks by the Chairman, Mr. M.J. Brennen, a film prepared by the Open University describing materials and structures for wing designs was presented. Examples from early craft including the Jupiter and Puffin I and II were cited, and a current Open University design was discussed. The trend in materials choice is to use spruce for the tension and compression flanges of wing spars and balsa for the shear webs. Torsional stiffness is accomplished either by D-nose torque boxes of balsa wood or open bracing in connection with multiple spars to form equivalent torque boxes. The choice of balsa for web material is dictated by the effectiveness of a thicker section of an admittedly weaker material (than spruce or metal) in resisting buckling failure.

An interesting design concept entitled "The Newbury Manflier" was then presented by its originator, RADM H.C.N. Goodhart, (RN Rtd.) The craft is powered by two men in separate pods driving separate propellers and operating separate elevators. A study by Goodhart concluded that all of the one-man craft with the exception of the Gossamer Condor are too heavy and that the way to

reduce the weight of the structure is to reduce the bending moments on the wing spar (the principal structural member in the wing) and its consequent weight. Goodhart's design entails a 42-m wingspan with the manned pods mounted 9 m from the wingtips. The weight of the spar is less than 25% of that required if both men were in a single pod mounted in the middle of the wing. Goodhart's power requirements are 0.25 hp delivered in thrust or 0.31 hp at the pedals per man. The empty weight of the Newbury Manflier is 170 lbs, and the weight of the pilots is projected at 150 lbs each. Since, in a typical turning maneuver, the airspeed of the inner and outer wing tips would be 22 ft/sec and 29 ft/sec, respectively, with corresponding lift coefficients of 0.7 and 1.4, it would be necessary to utilize the elevators differentially to twist the wing in order to effect the necessary variation in angle of attack. Meanwhile, the pilots would have to supply the proper thrust individually and collectively to bank and turn the craft while maintaining altitude. Goodhard pointed out that warping the wings produced less drag for the necessary rolling moment than the use of ailerons. Work on The Newbury Manflier started in November 1976; because of a mishap, the schedule for a first flight has slipped from this spring to sometime next summer.

The latest work of Prof. H. Kimura (Nihon Univ., Japan) was then presented by Mr. F. Toh. Kimura has been active in man-powered flight since 1961; in 1965, the first of his designs (Linnet I) flew a distance of 15 m. Kimura's designs are characterized by a high-aspect-ratio wing with a pylon-mounted propeller over the rear of the wing and a tail mounted on a short boom behind the wing. The Linnet series of craft had a shaft drive transmitting power from the pilot to the propeller. The next (Egret) series utilized a belt drive, and the last and most successful airplane (Stork) has a chain-drive power delivery to the propeller.

The Stork has a 20-m wingspan, a 2.7-m-diam. propeller and weighs 36 kg. The ailerons are each approximately one-third of the span in length. The wing spar is a combination of spruce and balsa wood. The propeller is covered in laminated balsa at the leading edge and styrene paper further aft. The fuselage frame is of chrome-molybdenum steel tubing. Kimura found that polishing the leading edge of the wing surface improved performance significantly. Recently, the Stork was flown a straight-line distance of almost 7000 ft.

The first session of the meeting continued with a discussion of the rules for the new $100,000 Kremer Cross-Channel Competition for man-powered aircraft. It was stated that the crossing would be from England to France and that a slope-ramp launch would be permitted because of the difficulty of siting a suitable runway on the coast. The craft, moreover, would have to demonstrate its sustained man-powered capabilities over level ground to insure that the cross-channel flight would not be in an essentially soaring mode.

There was also discussion of the difficulties faced by the pilot in pedaling strenuously to propel the craft while simultaneously controlling it with his hands; the possibility of immobilizing his upper body with a suitable harness so that he could more easily control the plane was raised. A free-ranging discussion involving man-powered ornithopters, other man-powered craft that do not require much take-off space, steel wing-spars, and the like followed. The point was made that a more "robust" craft would be needed for the Channel crossing, but nothing was mentioned of the more "robust" pilots that would be needed to power the craft.

The second and final session of the meeting was devoted to the report of Peter Lissaman on the Gossamer Condor program, headed by Dr. Paul MacCready, which helped the American balance of payments by £50,000. Lissaman discussed the power capability to weight ratio of animals that decreases with increasing animal weight. It seems that a human is the largest animal physically capable of self-powered flight. The studies of the California team indicated that a wing span of 30 m was optimum and that a "standard" athlete capable of 0.3-hp sustained output could power the airplane. The structure of the wing was externally braced with steel wire, a canard foreplane was tilted for turning, and the wings were warped to effect the "reverse" aileron needed to prevent roll during turns.

Though the program started only 18 months ago, computer studies on all aspects of the design were carried through to the successful system. In

fact, five days after the initial concept, the first Gossamer Condor had already flown. Though Lissaman indicated that there was nothing critical about the final design, it must be said that his group had extensive experience with hang-glider design and testing before embarking on the Gossamer Condor Program.

Lissaman stressed the ease with which the Gossamer Condor can be flown and noted that males and females from 14 to 60 years of age and of "all" sexes had piloted the plane. Indeed, a 60-year old grandmother (no doubt in superb condition) had flown.

The Man-Powered Aircraft Group is enthusiastically gearing up for an assault on the Channel. If the laws of physics did not have to be satisfied, some of the more "spirited" in the audience would no doubt be capable of flying across the Channel without any airplane at all. (Martin Lessen)

PSYCHOLOGICAL SCIENCES

THE ASSESSMENT OF HUMAN RELIABILITY IN MAN-MACHINE SYSTEMS

Whether reliability is about machines or men, the emphasis is failure and its probability of occurrence. It was human error that received primary attention at a Colloquium on Human Reliability in Man-machine Systems held at The Institution of Electrical Engineers (Savoy Place, London) on 20 December 1977. In recent years there has been a heightened awareness that man-machine system reliability is not a function of machine failure alone—system personnel make errors also.

Engineering psychologists use two approaches in their analyses of human error in systems. One, a qualitative approach, can be called a critical incident technique that requires the analysis of system failures assignable to personnel. More often than not these data turn out to be detailed accounts of accidents. One does not have to be a psychologist to uncover human errors in accidents—indeed, most accident analysts are not. More than anything else, accident analysts must know the system and the contingencies associated with its operation so that the steps and causes leading to an accident can be identified. Once the causes are established, remedies can be devised. The Colloquium featured two speakers in this category. One was D.M. Hunns, engineer (UK Atomic Energy Authority, Warrington), who analyzed a train crash in the Clayton tunnel on the Brighton-London run in 1861, and the other was M.F. Alnutt, psychologist (Army Personnel Research Establishment, Farnborough, Hants), who examined several aircraft accidents.

The second technique of human error analysis that engineering psychologists use runs parallel to the methods that reliability engineers employ in their failure analyses of hardware. The hardware approach is to build an empirical data bank of failure probabilities for equipment parts and components under various operating conditions, and to synthesize probabilities from the data bank and extrapolate an estimate of failure for the new system. It cannot be said that engineering psychologists have been able to carry out these steps with the success that hardware engineers have had, but some have started work on data banks that will store error values for human response "elements" under various conditions. The hope is that the information on response elements can be synthesized into error rates for complex behavior sequences comprised of the elements and then combined with hardware error rates to give reliability estimates for the system as a whole. The goal is commendable.

The most interesting part of the Colloquium was when D.E. Embrey (Applied Psychology Department, Univ. of Aston, Birmingham) expressed his doubts about an approach to human reliability that imitates hardware methods, and then added ideas of his own on a new approach. The refreshing thing about Embrey's thinking is that he faces human reliability as the behavioral problem that it is, and seeks to solve it with the ideas and methods of psychology.

Embrey had four basic criticisms of engineering psychologists who advocate imitation of the reliability methods of hardware engineering:

1. How is a behavioral element whose failure rate is determined and

entered into the data bank defined? Behavior is dynamic, multidimensional, and determined by many variables. What does it mean to decompose it into elements?

2. The meaningful collection of human error data is not easy. Watching people work and tabulating their errors, or the automatic measurement of error, can yield measures of dubious accuracy. Error rates under these circumstances may be different than when performance is unobserved and unmeasured.

3. Humans often correct an error, which can reduce its significance. An error may exist in a small magnitude and only momentarily before it is corrected, and so its occurrence may be of no consequence for the system.

4. There is no evidence that the probabilities for task elements (if they could be defined) can be synthesized into a failure rate for the behavioral sequence as a whole.

Embrey's new psychological approach asserts that the unit for reliability analysis should be a goal-directed activity. Human behavior is constituted of goal-oriented sequences, he contends, and it is these sequences that Embrey believes can be objectively identified and used as the focus of analysis. The trick for reliability analysis, whether hardware or human, is to predict reliability for a new system, and Embrey proposes a plan of several steps. First, a population of goal-oriented tasks is specified, and error rates are determined empirically by testing subjects in each of them. Experts then rate the tasks on psychological factors known to affect human error rate, such as the quality of the displays, training, or motivation. These ratings are used to define a linear multiple regression equation that has the expert ratings as independent variables for the prediction of the task error rates that were found empirically. When the equation is established, a new task of the population can be rated for the error-sensitive factors by one or more experts and the ratings entered in the equation for a prediction of reliability; no empirical testing for the reliability of the new task is required. There would be various populations of tasks, and an equation would be worked out for each one.

Problems should be a challenge, not a deterrent, and Embrey's proposal has plenty of them:

1. What is a goal-oriented task? The method presumes that the beginning and end points of a behavioral sequence can be objectively identified, but behavioral sequences can have goals and subgoals about which there will be disagreement. If an operator has to throw four switches to start an engine, is each switch a goal or is the start of the engine the goal? And, a goal can be real enough but so remote as to be almost useless for Embrey's calculations, as the pilot's goal of London on a New York-London flight.

2. What are the defining rules for membership in a task population? Tasks can be complex and multidimensional, and the rules for their classification are, at most, crude.

3. Who are to be the expert raters assessing the dimensions of the task for error proneness? Indeed, is there any reason to believe that anyone can accurately evaluate a task and its operator for error potential?

4. What are the factors in tasks that affect error and what are the bases of the expert ratings? They will vary from task to task, and they could include all the variables known to psychology.

5. Most man-machine systems are complex and involve long operating sequences. In Embrey's method, any task that is assessed would be only one of a number entering the sequence. Can the reliabilities of the separate tasks be synthesized into the reliability for behavior in executing the sequence as a whole? As a corollary, but not incidentally, can the reliabilities for separate tasks be joined with hardware reliabilities and synthesized into system reliability?

Whatever the merits of present-day approaches to human reliability, Embrey's included, there are those who will not pay much attention to any of them because they see other ways of engaging the topic of human error in man-machine systems. One way is to forget about tallying error rates and concentrate on techniques of designing the system, and selecting and training personnel, to minimize error. Another way is to see the human operator in a redundant relationship with hardware as a means of increasing system reliability. An example is the failure task analysis technique that E.R. Jones (Head, Human Factors Engineering, McDonnell Douglas Corporation, St. Louis)

and his associates used for the Mercury manned-space system. Salient modes of equipment failure were calculated, and the system was designed and the personnel trained so that the astronaut could back up vital functions and take over when hardware failed (e.g., manual control when automatic control failed). Failure task analysis is an established technology in engineering psychology that has been put to valuable use in our time, and someday a formal model of human reliability, as Embrey envisions, might conceivably mature and be useful also. Such a model could stand in a complementary relationship with failure task analysis because it will make refined statements about human reliability possible, and it will allow estimates of how effective the human operator will be as a redundant subsystem if the role is assigned to him. (Jack A. Adams)

A MEASURE OF JOB ENRICHMENT

Management knows that poor morale among employees can cause low output and be costly, but when low morale drives personnel to quit the costs of recruiting replacements and training them can be even more. The billions which industry and the military spend each year on the training of new personnel could be reduced to a small fraction if employees were kept satisfied and in the job.

Job satisfaction is a many-splendored thing, and no one item or action can do it all, but one dimension that we have heard a lot about in recent years is job enrichment. The idea of job enrichment is straightforward: Avoid work monotony by increasing job variety and the worker will be contented. The quantity and quality of work output will be higher, turnover will be lower, and personnel costs will be less. But how do you know job enrichment when you have it? How is job variety defined? The intuition of an experienced worker or supervisor can be useful in job redesign, but science strives to replace intuition with objective methods, and Dr. Shlomo Globerson (Faculty of Management, Tel Aviv Univ.) is trying to do this for job enrichment.

A long-standing capability of industrial engineers is job analysis, similar to what once was called time and motion study, which specified and timed the elements and tasks of a job to give an objective statement of them. The usual goal of job analysis is work efficiency, but Globerson has asked the new question of how the measures of job analysis can be used to express an index of variety.

He uses these definitions:

Job: The aggregate of tasks assigned to a worker.

Task: A group of elements occurring in temporal sequence using the same displays and controls, and with a common purpose.

Element: A describable and measureable set of one or more fundamental motions.

Cycle time: Time required to complete a single task.

Element time: Time required to complete a single element.

Each element of a worker's task is timed, and these time measures are used to define an index of variety called Nonrepetitive Time. Counting each element only once, the number of *different* elements within a cycle are summed to provide the index. The higher the index the less repetitive the job.

In one of his studies (S. Globerson and E.R.F.W. Crossman, *Organizational Behavior and Human Performance*, 1976, 17, 231-240), Globerson computed the index for clerical tasks in one organization and warehouse operations in another, and he found a good correlation between the index and worker ratings of job interest and variety. In his most recent work, Globerson found that the higher the job in an organization the higher the value of the index. We all have known that higher level jobs tend to have more variety than low level jobs, and Globerson, in objectifying our common experience, provides further support for his index of job variety. The time measures that serve job analysis and its goals of work efficiency apparently can express an index of job interest as well. (Jack A. Adams)

NEWS & NOTES

NEWTONIAN SCIENCE IN TIME?

The UK Treasury in February issued a new £1 banknote replacing one of somewhat larger size that carried on one side a portrait of the Queen and on the other Britannia. The smaller note is billed as an aid to the blind to help them to distinguish between the £1 and other notes. It is of interest that Britannia has been replaced by Sir Isaac Newton, who is apparently recognized as the UK's most distinguished scientist. In addition to being an outstanding President of The Royal Society (he was re-elected annually from 1703 until his death in 1727), he was also Warden of the Mint. We doubt whether such changes reflect Britain's current financial status, the falling pound, or the gravity of the situation. In any event, it comes at a peculiar time when gravity itself is the subject of considerable scientific inquiry and speculation.

The disappearance of Britannia, the Roman symbol for Britain, from the £1 note, leaves her only on the new seven-sided 50 Pence coin. She came aboard British currency during the reign of Charles II (1649-1685) when the Duchess of Richmond modeled Britannia for the King in representation of the reverse of a Roman coin of Antoninus Pius AD 138-161.

With the circulation of the new note, Newton joins Wellington (£5), Florence Nightingale (£10), and Shakespeare (£20) on the UK's paper currency. Rule Britannia! See our next issue. (A.W.P. & V.S.H.)

PERSONAL

Professor Ian M. Allison, Professor of Experimental Mechanics, University of Surrey, has been appointed to the Chair of Mechanical Engineering and Head of the Department. He succeeds Professor J.M. Zarek.

Professor P. Grieveson, Professor of Extraction Metallurgy at the University of Strathclyde, has been appointed to the Chair of Applied Metallurgy at Imperial College, University of London.

Dr. Cyril Hilsum, Chief Scientific Officer at the Royal Signals and Radar Establishment, Malvern, has recently been appointed visiting professor in the Department of Applied Physics and Electronics at the University of Durham.

Dr. R.B. Jewell, Reader in Experimental Physiology at University College, London, has been appointed to a new Chair of Physiology at the University of Leeds from 1 September 1978.

Professor Michael J. O'Hara, of the Grant Institute, University of Edinburgh has been appointed to the Chair of Geology at the University College of Wales, Aberystwyth, from 1 October 1978.

OBITUARIES

Christopher Hook, the inventor of the first fully-submerged and incidence-controlled hydrofoil, died in February at the age of 75. Although his inventions were taken up and further developed by France, Germany, and the US, he was never able to obtain recognition or financial support from the British government. In the early 50s, his plans were backed by the American National Advisory Committee for Aviation. He later worked with Gottard Sachsenberg, the German hydrofoil expert, who wrote that Hook's hydrofin was superior to all boats of similar size built according t other hydrofoil systems. Hook also designed the Flying Broomstick, a rev lutionary catamaran with hydrofoils looking somewhat like a trampoline.

Dr. Edward Arthur Perren, CB, FRIC, Director of the Chemical Defence Experimental Establishment (CDEE), Porton, from 1955-1961, died 5 February at the age of 77. Practically his whole career was spent with the CDEE, his having joined the Experimental Station (as it was then called) in 1922. His early work was concerned with the dispersion of substances by explosives and the development of smoke devices. His ability and versatility soon led him into administrative posts at which he excelled. In 1949 he served a two-year appointment on an exchange basis as Director of the Canadian counterpa of CDEE, the Suffield Experimental St tion in Alberta. On his return to Britain in 1951, he was appointed Superintendent of Research at CDEE, a post he held until his appointment as Director in 1955. He retired in 1961, but later on the disestablishment of CDEE, he headed a small group engaged in research on the synthesis of organic compounds of importance to chemical defense. This allowed him to return to his original love, organic chemistry. He finally retired in 1969.

ONRL REPORTS

R-12-77 A SAMPLING OF MILLIMETER WAVE TECHNOLOGY IN EUROPE—FALL 1977 by F.C. Essig (Proprietary information; Distribution limited to US Government Agencies only)

A summary of observations made on millimeter wave technology in the United Kingdom, the Federal Republic of Germany and the Netherlands during the Fall, 1977 is given. The report outlines available data on millimeter wave propagation and scattering phenomena in European weather models, the radar and radiometric properties of targets and terrain, and examples of component development relevant to the millimeter wavelengths. Some opinions on millimeter waves as an option for all-weather target classification and terminal guidance are offered.

R-13-77 A VIEW OF SURFACE ACOUSTIC WAVE TECHNOLOGY IN THE UK, FALL 1977 by F.C. Essig (Proprietary information; Distribution limited to US Government Agencies only)

The findings of the author's survey of a representative group of United Kingdom research and development organizations working in the field of SAW technology are presented. Current areas of interest in the United Kingdom, such as Surface Skimming Bulk Waves (SSBW), Magnetostatic Surface Waves (MSW), SAW-CCD Fourier Transform Signal Processors and Pulse Compression Filter Techniques are outlined.

C-1-78 THE 45TH MEETING OF THE STRUCTURES AND MATERIALS PANEL OF THE ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT (AGARD) by I.M. Bernstein

The results of an AGARD meeting on nondestructive inspection techniques as well as a planning session on corrosion fatigue testing are reported. Designers and users of aircraft components and structures discussed the need for reliable crack detection procedures. The importance of both automated techniques and human inspection were emphasized. The corrosion fatigue program will serve as the topic for a future AGARD meeting.

C-2-78 QUANTUM-ELECTRONICS—A NATIONAL CONFERENCE AT SOUTHAMPTON by V.N. Smiley

At the University of Southampton, a National Conference on Quantum Electronics was held 14-16 September 1977. This is the third in a series of such conferences. The topics included laser theory, superfluorescence, laser applications to atomic and molecular physics, scattering pollution monitoring, nonlinear optics, isotope separation and biomedical applications. This report provides some general comments on the meeting as a whole and summarizes a few of the most interesting papers.